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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DIVISION INTERNAL NOTE

SELECTION OF LANDING AIRFIELDS FOR SHUTTLE ORBITERS WITH VARIOUS CROSSRANGES

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LANDING AND RECOVERY DIVISION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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1.0 SUMMARY

The selection of airfields to support shuttle orbiters is required to aid in design development and operations planning. This paper reports a study resulting in the selection of a minimum number of unique airfields that provide the maximum number of landing opportunities possible and the minimum durations of in-orbit waits possible for shuttle orbiters with hypersonic crossranges of 100, 150, 200, 250, 500, 1100, and 1500 n. mi. Three example mission profiles were used for each example orbiter: (1) A 28.5° inclination, 100 n. mi. altitude mission, (2) a 55° inclination, 270 n. mi. altitude mission, and (3) a 90° inclination, 400 n. mi. altitude mission.

The airfields were selected from those currently available in the free world. They are the best equipped airfields available and should require little, if any, modification to support shuttle landings. These airfields were selected for four distinct types of orbiter landing opportunities. The first type was the planned end-of-mission landing opportunity, the second was the once-per-day landing opportunity within the continental United States, the third was the end-of-first-revolution landing opportunity, and the fourth was the emergency landing opportunities throughout the world. Unique sets of airfields were selected for the entire range of mission profiles for each crossrange considered. Specific subsets were then selected for each mission profile.

Based upon the analysis of all the generated data associated with these airfield selections, it is recommended that the shuttle orbiter should be designed for a hypersonic crossrange not less than 200 n. mi. to optimize the number of support airfields required and the duration of in-orbit waits required. It is also recommended that the orbiter be designed to land on runways of not more than 10,000 feet in length and with support capability for 100-psi tire pressure and an equivalent single-wheel load of about 50,000 lb. Consideration should be given to the cost of the number of airfields required, the cost of modifying the airfields as required, the in-orbit waits required, and the hypersonic crossrange desired in all shuttle program design efforts.

2 0 INTRODUCTION

This paper discusses the findings and recommendations resulting from a study designed to select specific airfields to support landings of example space shuttle orbiters with various hypersonic crossranges The space shuttle orbiter is a single-unit vehicle similar to a large jet transport aircraft in appearance, size, and landing characteristics As such, it will require modern, well-equipped airfields for landings

The rationale used and the assumptions made for the selection of specific airfields is discussed This is followed by a discussion of the systematic selection of airfields The associated data are then analyzed to optimize the crossrange, in-orbit wait, and number of support airfields Finally, recommendations for the shuttle program are given

3 0 GUIDELINE EXPLANATION

The airfield selection procedure followed the guideline that a minimum number of unique airfields be selected which will provide the maximum number of landing opportunities and the minimum durations of in-orbit waits possible for shuttle orbiter crossranges of 100, 150, 200, 250, 500, 1100, and 1500 n mi Such a unique set of airfields will provide coverage for the entire range of mission profiles assumed applicable to the shuttle program

4 0 ASSUMPTIONS EXPLANATIONS

Eleven major assumptions were made to allow a consistent analysis and selection of airfields These assumptions are discussed in the following paragraphs

4 1 Mission Profile

To limit the number of mission trajectories studied, it was assumed that the shuttle orbiter would return from only earth orbital missions with inclinations ranging from 28 5° to 90° and from circular orbits having altitudes 100 n mi to 400 n mi This range of missions includes most of the missions presently considered for shuttle reentries To represent this mission range, three specific mission profiles were selected for detailed analysis The first profile analyzed was one with an inclination of 28 5° and an altitude of 100 n mi , which resulted in the shortest longitudinal spacing between two groundtracks traced on the earth's surface by sequential shuttle

revolutions (22 5°) (fig 1) The second profile was one with an inclination of 90° and an altitude of 400 n mi , which was slightly beyond the presently designed shuttle orbiter reentry heating load capabilities and provided a reasonable maximum spacing between sequential shuttle groundtracks (25°) The third profile was one with an inclination of 55° and an altitude of 270 n mi , which is the present design reference mission for the shuttle support of the planned space station and is of primary interest All three mission profiles were simulated on an 1108 Univac computer by using the Lunar Trajectory Program (LTP) No E020 Each simulated mission trajectory was then applied to the Airfield Accessibility Program (AIRAC) No E021 on the Univac 1108 to determine the frequency of landing opportunities provided by the selected airfields All the data generated and analyzed from these three specific mission profiles represent data for the full range of missions assumed applicable to the shuttle program

4 2 Launch Site

Kennedy Space Center (KSC) was assumed to be the launch site for the space shuttle The location of the launch site determines, in part, the location of the airfields required

4 3 Shuttle Crossrange

Seven specific shuttle orbiter hypersonic crossranges were assumed as independent variables in the selection of seven sets of landing support airfields These crossranges were 100, 150, 200, 250, 500, 1100, and 1500 n mi The upper limit of 1500 n mi was used since this crossrange is the high crossrange shuttle design goal The lower limit of 100 n mi crossrange was assumed because no indications presently exist that the crossrange will be less The other crossranges were assumed to give random data points No atmospheric jet cruise capability or in-orbit maneuvering was assumed available for crossrange assist

4 4 Worldwide Airfields

Selecting worldwide airfields from only those in the free world is assumed because of possible political and military implications The free world excludes all countries which, under present conditions, would not be likely to cooperate with the United States in this type of program

4 5 Runway Length

The assumption of using only airfields with runway lengths of 10,000 ft or more was derived from analyzing the number of airfields of various lengths available within the free world

The number of free world airfield runways with lengths of 8,000 ft and above are tabulated in table I The largest number available, naturally, have runway lengths of 8,000 ft or more, but, those currently available runways in excess of 12,000 ft in length are very few As can be seen, though, a significant number of airfields exist with runway lengths of 10,000 ft or greater This information indicates that it should be possible to select airfields from those having runway lengths of 10,000 ft or greater to provide an acceptable and reliable support concept Some continental United States (CONUS) military airfields having shorter runway lengths were selected, though, to provide the required coverage These airfields are extendable at least to 10,000 ft

4 6 Runway Surface

Constraining the airfields used to those having runway surfaces of only concrete or asphalt results from the fact that these surfaces are usually strong enough to support the landing weights expected for the shuttle, which is similar to the landing weights exerted by large jet transport aircraft Most of these runway surfaces will support aircraft exerting at least a single-wheel load of about 50,000 lb with a tire pressure of about 100 psi (fig 2 and fig 3) Some asphalt runways, though, are not strong enough to support such weights and are eliminated from consideration Other surfaces that are used for runways will not hold up to such weights under most circumstances and are not considered in the selection process From table I, most of the runway surfaces for runways ranging in length from 8,000 ft to 14,000 ft are of either concrete or asphalt construction

4 7 Navigational Aids

In order to make use of available ground systems, the shuttle orbiter should interface with aircraft-type navigation equipment presently available The preferred ground navigational aid for present-day landings is the instrument landing system (ILS) The second choice is the ground-controlled approach (GCA) system The third choice is either the precision approach radar (PAR) or the approach surveillance radar (ASR) If an airfield possesses a VHF omnidirectional range (VOR) system, tactical air navigation (TACAN)

UHF pulse-type omni range and distance measuring equipment, a combination VOR and TACAN (VORTAC), distance measuring equipment (DME), or direction finder (DF) equipment, some instrument ground assistance from the airfield can be obtained for approach and landing An airfield possessing none of these aids would require a visual landing which would be totally unaided This is assumed undesirable for such a vehicle as the shuttle

4 8 Runway Elevation

Airfield runway elevations were assumed limited to 4,000 ft or less above mean sea level because higher elevations require longer runways for landings and take-offs and because airfields at the higher elevations are often surrounded by high mountains that could exceed the shuttle's cruise, approach, and go-around altitudes

4 9 Weather

Even though the shuttle landing may be totally automated, conditions such as high winds, low visibility, low ceilings, thunderstorms, and snow, could dangerously affect a landing It is, therefore, very highly desirable to use airfields where acceptable weather prevails In this paper, "acceptable weather" was assumed to exist at an airfield when the frequency of occurrence of instrument flight rule (IFR) weather minima was below about 10 percent for any month (this weather minima was derived from that recorded at the selected airfields [see the appendix]) The worst minimum was about 10 percent in frequency of occurrence which resulted from the worst minimum available at the airfields considered This weather criteria concerns only visibility and ceiling limits and was used because of the lack of any firm weather constraints for the shuttle

4 10 Obstructions

Since the shuttle will probably have the capability for a single go-around on the first landing attempt, high obstructions in and around the airfield would be dangerous Airfields with such obstructions, therefore, were not selected, as well as airfields located within densely populated metropolitan areas

4 11 Airfield Facilities

Several facilities were assumed to be required at or near the airfields considered for selection A communications system was assumed required to allow for message and information transmittal to and from the NASA control centers Repair and maintenance facilities were assumed required to allow repair and turnaround of the orbiter for either atmospheric or space flight, depending upon the landing site Medical facilities were assumed necessary within the local area of an airfield to provide medical aid if required A weather forecasting facility within the local area was assumed required to predict the weather for the time of landing Transportation by road, rail, or water was assumed required, to provide an alternate access to the airfield by NASA personnel and equipment

5 0 END-OF-MISSION AIRFIELD

To alleviate the necessity of postmission flybacks to the launch site and to provide for quick turnaround and refurbishment of the shuttle orbiter, a fully-equipped airfield will have to be constructed at the launch site, assumed to be KSC This airfield would be the primary end-of-mission landing site, and would require the highest level of approach, landing, and postlanding operational support The missions would have to be designed to normally end at KSC

6 0 CONTINENTAL UNITED STATES SUPPORT AIRFIELDS

To guarantee the desired quick refurbishment and reuse of the shuttle and to obtain quick access to the returned cargo, passengers, and crew, landing opportunities within the CONUS are required as often as possible The airfields to support the CONUS landings of the shuttle orbiter are constrained to provide at least one landing opportunity per day within the CONUS. This constraint can be met since the motion of the orbiter in its orbit relative to the daily rotation of the earth places the shuttle over the CONUS at least twice per day and at least one of these passes should be within the orbiter's hypersonic crossrange capability to reach an acceptable airfield These airfields are further constrained to be only military or NASA owned and operated to avoid interruptions of existing heavy civilian air traffic, for safety purposes, and for security

6 1 Orbital Considerations

In this paper, it has been assumed that whenever a shuttle groundtrack passes within the shuttle's crossrange capability of an acceptable airfield, the shuttle has an opportunity to land at that airfield Using this assumption, the general location and the exact number of the CONUS support airfields are determined in the following discussion

For a shuttle flying a mission profile within the range of missions considered in this paper, the longitudinal spacing between the shuttle's sequential groundtracks is, at most, 25° This spacing is for the 90° inclination, 400 n mi altitude mission (see fig 1), therefore, the groundtrack that follows two sequential groundtracks by about 1 day will pass somewhere between the two Thus, at least once per day the shuttle will pass somewhere over a specific area on earth that has a span of, at most, 25° in longitude By selecting a group of airfields within this area of passage within the CONUS, a landing opportunity at least one time per day can be guaranteed

The center of this area of passage should be limited in latitude to below about 30° N to contain airfields within the minimum crossrange (100 n mi) considered from a 28 5° inclination mission ' From figure 4, then, the area of passage longitudinal spread, would be at most about 620 n mi from center to extremity Its total span would be about 1240 n mi when centered at 30° N latitude

Assuming a shuttle orbiter hypersonic crossrange of 100 n mi , the shuttle will be capable of flying from the edge of a 200 n mi diameter circle to an airfield located at the center of the circle Assuming a 1240 n mi length for the area of passage, then, at least seven optimally located airfields will be required to cover this area (1240 n mi divided by 200 n mi = 7 as the inclusive integer). Assuming a crossrange of 150 n mi , at least five airfields will be required For a 200 n mi crossrange, at least four airfields will be required For a 250 n mi crossrange, at least three airfields will be required For a 500 n mi crossrange, at least two airfields are required For a 1100 n mi crossrange, at least one is required For a 1500 n mi crossrange, only one is required

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' A variable area-of-passage span is due to the fact that the shortest distance between successive groundtracks varies with the latitude of the measurement and the mission altitude and inclination

As can be seen from figures 5 through 11, the minimum number of acceptable CONUS support airfields developed above cannot always be found, and one additional airfield may be needed to completely cover the area of passage To alleviate some of the necessity for an additional airfield, the end-of-mission airfield, assuming that it will be built at KSC, is considered to cover the eastern end of the area of passage The other CONUS support airfields to be selected are to the west of KSC

Another limiting factor to the location of these airfields is the desire for an airfield to support possible end-of-first-revolution landings This airfield must be within orbiter crossrange of the end-of-first-revolution longitude line located at about 102 5° W longitude (section 7 0) Therefore, the required once-per-day landing opportunity support airfields will be selected from those military airfields located west from KSC to an airfield within range of 102 5°W longitude

6 2 Requirements

In summary, these airfields are to possess the following characteristics, previously discussed They must

a Be located within the CONUS

b Be a military or NASA airfield

c Be located outside any densely populated metropolitan area

d Be located within the area of passage discussed in section 6 1

e Be less than 4,000 ft in elevation

f Possess a runway at least 10,000 ft long or extendable to 10,000 ft

g Possess a runway surface of concrete or asphalt with at least support capability for a single-wheel load of about 50,000 lb and a tire pressure of about 100 psi

h Possess year-around weather such that instrument flight rule (IFR) minimum conditions occur less than 10 percent of the time during any month

i Possess an ILS and other usual terminal guidance and navigation equipment

j Possess repair and maintenance facilities

k Have medical facilities available in the local area

l Have weather forecasting facilities in the local area

m Be accessible by road, rail, or water

n Have obstruction-free runways and approach paths

o Have capabilities for communications with NASA control centers

The possibility of having to use any one of these airfields except the primary end-of-mission airfield and the end-of-first-revolution support airfield is low, though, since all normally planned CONUS landings will occur at the launch site with backup landing coverage available at the end-of-first-revolution airfield These airfields, in general, will not require installation of special operational support equipment prior to a mission.

6 3 Continental United States Support Airfields Selections

Seven separate sets of airfields will be selected to provide the once-per-day landing opportunities within the CONUS, based upon the seven hypersonic crossranges considered for analysis--100, 150, 200, 250, 500, 1100, and 1500 n mi

6 3 1 <u>Airfields to support a 100 n mi crossrange orbiter</u> --Assuming that the shuttle orbiter has at least a 100 n mi hypersonic crossrange, a minimum of seven CONUS airfields will be required to support the once-per-day landing opportunities Seven acceptable airfields, though, are not available to totally cover the area Eight such airfields, however, can be found to provide this coverage (fig 5) The first airfield selected is the assumed end-of-mission airfield that would be built at KSC Within 200 n mi of KSC, to the west, and as far south as possible, is the second acceptable airfield--Moody AFB, Georgia (table II) The runway at this airfield, though, will have to be extended if the orbiter requires over 8,000 ft of runway to land and take-off To the west, and within 200 n mi of Moody AFB, and as far south as possible, is the third selected airfield--Eglin AFB, Florida This airfield meets all the desired requirements

listed in Section 6 2 The fourth selected airfield is New Orleans NAS, Louisiana This airfield meets all of the requirements except for runway length and navigation aids The runway will have to be extended if the orbiter requires over 8,000 ft for landings and take-offs An ILS will also have to be provided at the field if required by the orbiter The fifth selected airfield is England AFB, Louisiana The runway will have to be extended if over 9,300 ft are needed for orbiter landings and take-offs, and an ILS will have to be provided at the field if required The sixth selected airfield is Ellington AFB, Texas This runway will have to be extended if over 9,000 ft are required for orbiter landings and take-offs, and an ILS will have to be added if required The seventh selected airfield is Bergstrom AFB, Texas, and it meets all the necessary requirements The eighth, and final, selected airfield is Laughlin AFB, Texas, which is within 100 n mi crossrange of 102 5° W longitude This runway will have to be extended if more than 8,300 ft are needed for orbiter take-offs and landings

This set of CONUS airfields to support a shuttle orbiter with a crossrange of at least 100 n mi may be expensive to utilize because of the expense of using the large number of airfields and since five airfields may need their runways extended, and three may need ILS's added

6 3 2 Airfields to support a 150 n mi crossrange orbiter -- Assuming that the shuttle orbiter has at least a 150 n mi hypersonic crossrange, a minimum of five airfields will be required to support the once-per-day CONUS landing opportunities (fig 6) The first airfield selected within the area of passage is the assumed one that would have to be built at KSC About 300 n mi west of KSC, and as far south as possible, is the second selected airfield--Eglin AFB, Florida, which meets all the previously listed requirements The third airfield selected is England AFB, Louisiana This airfield is about 300 n. mi. west of Eglin AFB and the farthest south military field in this area This airfield meets all of the listed requirements except for having at least a 10,000-foot runway and an ILS If more than 9,300 ft are required by the orbiter for landing and take-off, the airfield can be extended An ILS, if required, will also have to be added The fourth airfield selected to support a 150 n mi crossrange is Bergstrom AFB, Texas, located about 300 n mi west of England AFB This airfield meets all of the listed requirements. The fifth and final CONUS airfield selected for the 150 n mi crossrange case is Laughlin AFB, Texas It is within 300 n mi of Bergstrom AFB and within 150 n. mi of 102 5° W longitude. This airfield meets all of the requirements except for runway length The runway can be extended if more than 8,300 ft of runway are needed

6 3 3 Airfields to support a 200 n mi crossrange orbiter -- Assuming a 200 n mi. hypersonic crossrange for the shuttle orbiter, a minimum of four CONUS airfields will be required (fig 7) The first selected CONUS airfield, again, is the assumed one that would have to be built at KSC Within 400 n mi and to the west of KSC is Eglin AFB, Florida--the second selected airfield for this crossrange case It meets all of the requirements. The third selected airfield is Barksdale AFB, Louisiana, which is within 400 n mi of Eglin AFB and to the west of Eglin AFB. It meets all of the requirements for a CONUS support airfield The fourth, and final, airfield selected for this case is Laughlin AFB, Texas, which is within about 400 n mi and to the west of Barksdale AFB It is also within 200 n. mi crossrange of 102 5° W longitude This airfield meets all of the requirements except for runway length It may need extending, as previously mentioned This extension may be an added expense if a 200 n mi crossrange is used for the shuttle orbiter

6 3 4 Airfields to support a 250 n. mi crossrange orbiter -- For a 250 n mi crossrange orbiter, a minimum of three CONUS airfields are required, but, three acceptable airfields cannot be found to totally cover the area of passage (fig 8) Four acceptable airfields can be selected, though, that will provide the required support The first airfield selected, again, is the assumed KSC field The second selected airfield is Columbus AFB, Mississippi, and the third is Bergstrom AFB, Texas, both of which meet all the requirements The fourth selected airfield is Biggs AAF, Texas. This airfield is within the required 500 n mi of Bergstrom AFB and is within 250 n mi crossrange of the end-of-first-revolution longitude (102 5° W) This airfield meets all the requirements except that it lacks an ILS If an ILS is required, it will have to be added This will be an added expense The 250 n mi crossrange case has been thoroughly analyzed in reference 1

6 3 5 Airfields to support a 500 n mi crossrange orbiter --For a 500 n mi crossrange orbiter, a minimum of two CONUS airfields are required (fig 9) The first CONUS airfield selected is the assumed KSC field The second airfield selected is Bergstrom AFB, Texas, which meets all the listed requirements and is within 500 n mi crossrange of the end-of-first-revolution longitude This set of CONUS airfields is the least expensive one considered, so far, since no runway lengthening is required and no additional ILS is required

6 3 6 Airfields to support a 1100 n mi crossrange orbiter -- For a 1100 n mi crossrange orbiter, a minimum of one CONUS airfield is required, but, the one airfield at KSC will not be within the 1100 n mi crossrange from the end-of-first-revolution longitude (fig 10) As a result, two CONUS airfields are necessary The first airfield selected is, of course, the assumed KSC field The second

airfield selected is Bergstrom AFB These two meet all of the desired requirements

6 3 7 <u>Airfield to support a 1500 n mi crossrange orbiter</u> -- Assuming a 1500 n mi crossrange, only one CONUS airfield is necessary, and it is the one that would be built at the assumed launch site--KSC (fig 11) This would, no doubt, be the least expensive CONUS support concept to establish as far as additional ground support at other landing sites is concerned

7 0 FIRST REVOLUTION SUPPORT AIRFIELD

The orbiter insertion orbit is currently designed to have a 100 n. mi altitude apogee and a 50 n mi altitude perigee, requiring a subsequent circularization maneuver to raise the perigee to about 100 n mi in altitude If this circularization maneuver fails, the orbiter will be forced to reenter near the end of the first revolution because of contact with the earth's atmosphere An airfield within orbiter crossrange of the end of the first revolution passage over the CONUS is, therefore, required to support such a possible occurrence

In the case of a system malfunction during or immediately after the launch phase, a prime method of abort will be for the shuttle orbiter to reach a contingency orbit and then deorbit and land at the end of the first revolution This indicates the desirability to have an airfield selected to support such possible aborts Such an airfield also will usually be within orbiter crossrange one revolution following a passage of KSC if for some reason a landing cannot occur at KSC

7.1 Orbital Considerations

Such an airfield to support the preceding cases will be constrained in location by orbital considerations If the shuttle aborts from its insertion orbit or a contingency orbit during the first revolution, it will be from a low-altitude earth orbit of approximately 100 n mi in altitude Even if the shuttle reenters from a normal mission at the end of the first revolution, it will probably be deorbiting from a low-altitude earth orbit For the total mission inclination range (28 5° to 90°), then, the longitude of the shuttle would be about 22 5° to the west of the launch site at KSC (fig 1) This longitude, after the first revolution, would be about 102 5° W The airfield selected, therefore, will have to be located within orbiter crossrange of this 102 5° W longitude

7 2 Requirements

The factors described illustrate that the first revolution support airfield has a possible high frequency of use and, as such, should require a significant level of operational support on site above the after-the-fact low level of support required at the other alternate CONUS airfields to the west of KSC

The following list summarizes all of the requirements that should be met by an acceptable end-of-first-revolution support airfield It must

a Be located within the CONUS.

b Be a military or NASA airfield

c Be located outside any densely populated metropolitan area

d Be located within the area of passage--below about 30° N latitude--and within orbiter hypersonic crossrange of about 102 5° W longitude for all of the missions considered

e Be less than 4,000 ft in elevation

f Possess a runway at least 10,000 ft long or extendable to 10,000 ft

g Possess a runway surface of concrete or asphalt with at least support capability for a single-wheel load of 50,000 lb and a tire pressure of about 100 psi.

h Possess year-around weather such that instrument flight rule (IFR) minimum conditions occur less than 10 percent of the time during any month.

i Possess an ILS and other usual terminal guidance and navigation equipment

j Possess repair and maintenance facilities

k Have medical facilities available in the local area

l Have weather forecasting facilities in the local area

m Be accessible by road, rail, or water

n Have obstruction-free runways and approach paths.

o Have capabilities for communications with NASA control centers

7 3 First Revolution Support Airfield Selection

For each of the seven crossranges considered, an airfield is selected to provide an end-of-first-revolution landing opportunity These same airfields were also selected previously as part of the sets of CONUS support airfields discussed in section 6 3

7 3.1 The airfield for a 100 n mi. crossrange orbiter --Assuming that the shuttle orbiter has a hypersonic crossrange of 100 n mi , only one acceptable airfield is within 100 n mi of the end-of-first-revolution longitude This airfield is Laughlin AFB, Texas, which is selected as the first revolution support airfield for this case The runway at Laughlin AFB will have to be extended if more than 8,300 ft of runway are required for the orbiter All the other requirements as listed in section 7 2, however, are met by this airfield

7 3 2 The airfield for a 150 n mi crossrange orbiter --Assuming that the orbiter has a 150 n mi crossrange capability, the most acceptable airfield within this crossrange of the end-of-first-revolution longitude is also Laughlin AFB, Texas.

7 3 3 The airfield for a 200 n. mi crossrange orbiter --The airfield selected to support a 200 n. mi crossrange orbiter as an end-of-first-revolution landing site is, again, Laughlin AFB, since it is the most acceptable airfield within crossrange of the 102 5° W longitude line

7 3 4 The airfield for a 250 n. mi. crossrange orbiter --The airfield selected as the end-of-first-revolution landing site to support a 250 n. mi crossrange orbiter is Biggs AAF, Texas This airfield was selected since it is the most acceptable one within the assumed 250 n mi crossrange of 102 5° W longitude This airfield meets all of the listed requirements except for the desired navigation aids An ILS may need to be installed at Biggs AAF if the orbiter requires one

7 3 5 The airfield for a 500 n mi crossrange orbiter --The airfield selected as the end-of-first-revolution landing site to support a 500 n mi crossrange orbiter is Bergstrom AFB, Texas This airfield is the best qualified within the 500 n mi crossrange of the end-of-first-revolution longitude line (102 5° W) This airfield meets all of the listed requirements

7 3 6 The airfield for a 1100 n mi crossrange orbiter --The airfield selected as the end-of-first-revolution landing site to support a 1100 n mi crossrange orbiter is also Bergstrom AFB, which meets all the requirements for such a landing site

7 3 7 The airfield for a 1500 n mi crossrange orbiter.--The airfield selected as the end-of-first-revolution landing site to support a 1500 n mi crossrange is the same as the primary end-of-mission airfield--the assumed KSC field This airfield should more than meet all of the listed requirements

8 0 SUMMARY OF SELECTED CONTINENTAL UNITED STATES AIRFIELDS

In summary, the selected airfields to support landings of the shuttle orbiter within the CONUS can be classified as the primary end-of-mission airfield, the contingency CONUS airfields, and the end-of-first-revolution airfield The following list classifies the selected CONUS airfields for each of the seven hypersonic crossranges analyzed

A CONUS airfields for a 100 n mi. crossrange

1 KSC--end-of-mission

2 Moody AFB--contingency CONUS

3 Eglin AFB--contingency CONUS

4 New Orleans NAS--contingency CONUS

5 England AFB--contingency CONUS

6 Ellington AFB--contingency CONUS

7. Bergstrom AFB--contingency CONUS
8. Laughlin AFB--end-of-first-revolution

B. CONUS airfields for a 150 n mi crossrange

1. KSC--end-of-mission
2. Eglin AFB--contingency CONUS
3. England AFB--contingency CONUS
4. Bergstrom AFB--contingency CONUS
5. Laughlin AFB--end-of-first-revolution

C. CONUS airfields for a 200 n mi crossrange

1. KSC--end-of-mission
2. Eglin AFB--contingency CONUS
3. Barksdale AFB--contingency CONUS
4. Laughlin AFB--end-of-first-revolution

D. CONUS airfields for a 250 n mi crossrange

1. KSC--end-of-mission
2. Columbus AFB--contingency CONUS
3. Bergstrom AFB--contingency CONUS
4. Biggs AAF--end-of-first-revolution

E. CONUS airfields for a 500 n mi crossrange

1. KSC--end-of-mission
2. Bergstrom AFB--end-of-first-revolution

F CONUS airfields for a 1100 n mi crossrange

1 KSC--end-of-mission

2 Bergstrom AFB--end-of-first-revolution

G CONUS airfield for a 1500 n. mi crossrange

KSC--end-of-mission and end-of-first-revolution

9 0 LANDING OPPORTUNITIES AT SELECTED CONTINENTAL UNITED STATES AIRFIELDS

The landing opportunities provided by each of the selected CONUS airfields are illustrated in figure 12 and summarized in figure 13 for each of the three mission profiles analyzed and for each of the seven crossranges considered From each of the seven sets of CONUS airfields selected for each crossrange, a subset can be selected to provide the least duration of in-orbit waits before the occurrence of a landing opportunity from each of the missions considered This in-orbit wait is termed the "maximum in-orbit wait" (MIW) necessary to land at an airfield in the particular subset

The landing opportunity coverage by these subsets will provide for (1) an end-of-mission landing, (2) a once-per-day landing opportunity, and (3) an end-of-first-revolution landing opportunity These landing opportunities are discussed in the following paragraphs *

9 1 Landing Opportunities for a 100 n mi Crossrange Orbiter

Assuming a 100 n mi crossrange for the shuttle orbiter, the required landing opportunity coverage can be provided by subsets of from two to eight of the selected CONUS airfields, for this case, depending upon the mission profile

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*The data for this discussion were generated from the two computer programs--LTP and AIRAC

For the 28 5^{o} inclination, 100 n mi altitude mission profile, the minimum number of CONUS airfields to provide the desired landing opportunities is two. These airfields are the assumed field at KSC and Laughlin AFB To land at one of these two airfields, a 100 n. mi. crossrange orbiter would have to wait in orbit at most 15 revolutions before having a landing opportunity This 15-revolution MIW occurs six times in 114 revolutions or 7 days (see fig 12)

For a 55^{o} inclination, 270 n mi altitude mission profile, the required CONUS coverage is provided by the two airfields--KSC and Ellington AFB An MIW of 14 revolutions occurs two times in 104 revolutions or 7 days for this case. The 90^{o} inclination, 400 n. mi altitude mission profile requires eight CONUS airfields--(1) KSC, (2) Moody AFB, (3) Eglin AFB, (4) New Orleans NAS, (5) England AFB, (6) Ellington AFB, (7) Bergstrom AFB, and (8) Laughlin AFB. An MIW of 14 revolutions occurs one time in 95 revolutions or about 7 days in this case

In summary, to cover the total mission range, eight CONUS airfields will be required, however, for specific missions, subsets out of the eight airfields will provide the required coverage

9 2 Landing Opportunities for a 150 n mi Crossrange Orbiter

Assuming a 150 n mi crossrange for the shuttle orbiter, the required landing opportunities can be provided by subsets of from two to five of the selected CONUS airfields For the 28 5^{o} inclination, 100 n mi altitude mission, the minimum number of necessary airfields in the subset is two--KSC and Laughlin AFB Using these airfields for this mission, an MIW of 14 revolutions will occur five times in 113 revolutions or about 7 days The required coverage for a 55^{o} inclination, 270 n mi. altitude mission is provided by three airfields--KSC, Bergstrom AFB, and Laughlin AFB An MIW of nine revolutions occurs seven times in 99 revolutions or about 7 days for this case The 90^{o} inclination, 400 n mi altitude mission requires five CONUS airfields--KSC, Eglin AFB, England AFB, Bergstrom AFB, and Laughlin AFB An MIW of 15 revolutions occurs two times in 102 revolutions or about 7 days.

To summarize the CONUS airfields required to provide landing opportunities for a 150 n mi crossrange orbiter, a total of five selected airfields are required to cover the entire mission profile range. For specific missions, though, only subsets out of these five airfields are necessary to cover the three previously listed categories of CONUS landing opportunities

9 3 Landing Opportunities for a 200 n mi Crossrange Orbiter

Assuming a 200 n. mi crossrange this time for the orbiter, subsets of from two to four of the selected CONUS airfields are required for each mission profile For the 28.5° inclination, 100 n mi. altitude mission, a subset consisting of two airfields is required The airfields are KSC and Laughlin AFB, and they provide an MIW of 13 revolutions that occurs five times in 114 revolutions or 7 days. The required coverage for a 55° inclination, 270 n. mi altitude mission is provided by a subset of three airfields--KSC, Barksdale AFB, and Laughlin AFB These provide an MIW of 14 revolutions that occur two times in 99 revolutions The required coverage for a 90° inclination, 400 n mi altitude mission is provided by all four CONUS airfields for this case--KSC, Eglin AFB, Barksdale AFB, and Laughlin AFB. These provide an MIW of eight revolutions that occurs two times in 102 revolutions

In general, a total of four selected CONUS airfields are required to provide the designated landing opportunities for a 200 n. mi crossrange orbiter for the total range of missions considered, however, subsets out of these four provide the required coverage for specific missions

9 4 Landing Opportunities for a 250 n mi Crossrange Orbiter

If the orbiter has a 250 n mi. hypersonic crossrange, subsets of from two to four of the selected CONUS airfields for this case are required for each mission profile To support the 28 5° inclination, 100 n mi altitude mission, a subset consisting of two airfields is required These airfields are KSC and Biggs AAF They provide an MIW of 14 revolutions that occur five times in 113 revolutions The 55° inclination, 270 n mi. altitude mission requires two CONUS airfields--KSC and Bergstrom AFB. They provide an MIW of nine revolutions occurring seven times in 99 revolutions The 90° inclination, 400 n mi altitude mission requires four CONUS airfields--KSC, Columbus AFB, Bergstrom AFB, and Biggs AAF They provide an MIW of eight revolutions occurring one time in 102 revolutions

To cover the entire mission range, though, the four selected CONUS airfields are required for a 250 n. mi crossrange orbiter Subsets from these four can be used to cover specific missions, however

9.5 Landing Opportunities for a 500 n. mi. Crossrange Orbiter

For an orbiter with a 500 n. mi. crossrange, the two CONUS airfields selected to cover all mission ranges are required to cover each specific mission. These airfields are KSC and Bergstrom AFB. For a 28.5° inclination, 100 n. mi. altitude mission, these two airfields provide an MIW of 12 revolutions occurring five times in 114 revolutions. For a 55° inclination, 270 n. mi. altitude mission, they provide an MIW of nine revolutions occurring five times in 113 revolutions. For a 90° inclination, 400 n. mi. altitude mission, they provide an MIW of eight revolutions occurring one time in 102 revolutions.

9.6 Landing Opportunities for a 1100 n. mi. Crossrange Orbiter

For an orbiter with a 1100 n. mi. crossrange, the two CONUS airfields selected to cover all mission ranges are required to cover each specific mission. These airfields are KSC and Bergstrom AFB. For a 28.5° inclination, 100 n. mi. altitude mission, these two airfields provide an MIW of 10 revolutions occurring four times in 114 revolutions. For a 55° inclination, 270 n. mi. altitude mission, they provide an MIW of seven revolutions occurring eight times in 114 revolutions. For a 90° inclination, 400 n. mi. altitude mission, they provide an MIW of seven revolutions that occur one time in 102 revolutions.

9.7 Landing Opportunities for a 1500 n. mi. Crossrange Orbiter

For an orbiter with a 1500 n. mi. crossrange, only the one primary end-of-mission airfield that would have to be constructed at KSC is necessary to provide the required coverage. For a 28.5° inclination, 100 n. mi. altitude mission, KSC provides an MIW of 10 revolutions, occurring four times in 114 revolutions. For a 55° inclination, 270 n. mi. altitude mission, KSC provides an MIW of seven revolutions occurring eight times in 115 revolutions. For a 90° inclination, 400 n. mi. altitude mission, it provides an MIW of seven revolutions occurring two times in 102 revolutions.

10 0 WORLDWIDE SUPPORT AIRFIELDS

In the event of an emergency in orbit that requires an immediate deorbit and landing (an orbital abort), it may be impossible to reach one of the selected CONUS airfields In this case, airfields elsewhere in the world would be required, in addition, to support such emergency landings If such an emergency does arise, it is highly improbable that the shuttle could deorbit within one revolution (except during the first revolution following a launch, since this orbit will generally be 100 n mi in altitude or less, and the shuttle should be actively configured for such a deorbit during this time). An attempt to select emergency support airfields, therefore, will not be made to provide a landing opportunity for every revolution within any considered mission profile Also, since no airfields exist within large areas of the Pacific and Atlantic Oceans, a shuttle could quite often make more than one revolution without passing within range of an airfield The number of revolutions, or maximum in-orbit waits, before a landing opportunity occurs for the shuttle will be derived from the selection of a set of the best airfields available in the free world

10 1 Requirements

The requirements set up for these additional emergency support airfields can be relaxed from those for the CONUS airfields These emergency airfields will not require runway strengths as high as those of the CONUS airfields, since it can be assumed that the emergency airfields would be used only one time by the shuttle and not subjected to the wear and tear of possible repeated use Also, it can be assumed that lower level ground navigational aids would be acceptable at the emergency airfields, although, at least an ILS, GCA, PAR, or ASR is desirable. To be within crossrange of the 28 5° inclination mission, these airfields are limited to locations not above 30° N or below about 30° S latitudes Also, both military and civilian airfields were considered In summary, these airfields are to possess the following characteristics They must

a Be located within the free world countries

b Be located outside any densely populated area

c Be located between about 30° N and 30° S latitudes

d Be less than 4,000 ft in elevation

e. Possess a runway at least 10,000 ft long

f Possess a runway surface of concrete or asphalt with at least support capability for a single-wheel load of about 50,000 lb and a tire pressure of about 100 psi.

g Possess year-around weather such that instrument flight rule (IFR) conditions occur less than 10 percent of the time during any month.

h Possess an ILS or GCA and other usual terminal guidance and navigation equipment

i. Possess repair and maintenance facilities

j Have medical facilities available in the local area

k Have weather forecasting facilities in the local area

l. Be accessible by road, rail, or water

m Have obstruction-free runways and approach paths

n Have capabilities for communications with NASA control centers.

In conclusion, since these worldwide orbital emergency support airfields are selected to provide for the very low possibility of an untimely reentry that will not allow a return to KSC or an alternate CONUS airfield, they will require no premission operational support. Support will be provided at the airfield only when one of the selected airfields outside the CONUS has been selected (in real time) for an emergency landing Such support, as required, will be transported to the emergency support airfield as soon as possible to perform the required postlanding, pre-ferry, and take-off operations These outside the CONUS emergency support airfields are considered to require an operational support level similar to the alternate CONUS airfields discussed in section 6.2

10 2 Worldwide Support Airfields Selection

After considering all of the constraints previously developed, the free world airfields outside the CONUS remaining from which to select are listed in table III All the airfields listed in table II, not previously selected, may also be included in this group Some of the airfield in table III were found to be undesirable for use because of persistently bad weather, rugged surrounding terrain, or dangerous obstructions Galeao, Brazil, was deleted from consideration because of the obstructions of a mountain range within 8 miles of the field, which surrounds the airfield and Rio de Janeiro Conakry, Guinea, was deleted because of its persistently heavy rainy season from May to October, with a mean annual rainfall of 169 inches Conakry's drainage is also very inadequate after heavy rains El Libertador, Venezuela, was deleted since a mountain range running east to west with peaks of 7,998-ft elevation is located about 15 miles north of the airfield All of the airfields in South Vietnam were deleted from consideration because of the persistent rainy weather in this area, consisting of two heavy rainy seasons with a mean cloudiness of from 50 percent in April to 75 percent in December The airfields listed in Taiwan, likewise, were all deleted because they too are subjected to two monsoon seasons that could hamper an emergency type of landing Faaa, Society Islands, was deleted because it is located on a small island that rises to 7,000-ft elevation within 5 miles of its coast, and to the west about 10 miles is an 8,000-foot peak on an adjacent island Bangkok Intl , Thailand, is located in a densely populated city which could be endangered by an emergency landing Karachi Civil, West Pakistan, is subjected to severe dust storms in the summer and rains in the winter, which could hamper emergency landings. Udorn USAF, Thailand, was deleted from consideration due to its heavy rainy season from May to October Calcutta, India, was deleted since it has inadequate drainage and is subjected to a long monsoon season from May through October with a maximum of 45 inches of rain in September Bombay/Santa Cruz, India, was deleted since it also has inadequate drainage and is subjected to a long monsoon season from June through October with a maximum of 59 1 inches of rain in July Kuala Lumpur Intl , Malaysia Federation, was deleted since it is subjected to two monsoon seasons which limit flying activities Jorge Chavez Intl , Peru, was deleted because its prevailing low ceiling and visibilities require instrumented landings (IFR conditions) 70 percent of the time

Several airfields are located so close to others suitable for consideration that they each provide the same landing opportunities In these cases, only the airfield considered the best was not deleted Andersen AFB, Guam, was chosen in preference to Agana NAS, Guam, since Andersen AFB has a stronger runway surface and is better maintained Clark AB, Phillipine Islands, was chosen over Manila Intl , Phillipine

Islands, because its runway surface is stronger, and it is a USAF-controlled airfield. Ramey AFB, Puerto Rico, was chosen over Puerto Rico Intl , since Ramey AFB is a USAF base instead of civilian, and it has a stronger runway surface and an ILS and GCA Ramey AFB was chosen over Roosevelt Roads NS, Puerto Rico, since Ramey AFB has a stronger runway surface and has an ILS, whereas, Roosevelt Roads NS does not

From table III, only 12 airfields outside the CONUS remained from which to select those for the orbital abort support Several airfields within the CONUS remained, but, since landing opportunities are already provided by the previously selected CONUS airfields for overflights of the area from Florida to Arizona, only the airfields meeting the constraints of section 10 1, and located from about Davis Monthan AFB, Arizona, to the West Coast, as listed in table II, were retained as possibilities

By analyzing 7 days of the groundtracks of the three representative mission profiles considered in this study by use of the LTP program and by determining when the groundtracks come within orbiter crossrange of an airfield by use of the AIRAC program, it is possible to find one unique set of airfields that are the best available and provide the largest number of landing opportunities and smallest duration of in-orbit waits for the full range of possible shuttle missions, considering the seven analyzed orbiter crossranges

The first group of this set of airfields are the CONUS airfields previously selected for each crossrange case, since they are already available for support of previous mission phases and can also provide part of the worldwide orbital abort landing opportunities

One more CONUS airfield, located about 500 n mi or so to the west of Biggs AAF, could provide landing opportunities for at least one additional pass over the continent. Only three military airfields in this area provide any significant coverage (The available civil airfields only duplicate the coverage offered by the three military bases.) These airfields are Yuma MCAS/Yuma Intl , Arizona, Davis Monthan AFB, Arizona, and San Nicolas Is OLF, California Only one of these airfields is required and was selected, based on the groundtrack analysis

Analyzing the landing opportunities provided by each of the remaining airfields, the following (excluding the previously selected CONUS support airfields) provide at least one landing opportunity during a revolution that no other airfield provides and provide the minimum duration MIW's possible Darwin, Australia, N Djili, Congo, Honolulu Intl /Hickam AFB, Hawaii, Nandi Intl , Fiji Is., Lusaka Intl , Zambia,

Perth Intl , Australia, La Tontouta, New Caledonia, Andersen AFB, Guam, Ramey AFB, Puerto Rico, Kadena AB, Ryukyu Is , and San Nicolas Is OLF, California These airfields, plus the previously selected CONUS support airfields are the best available, provide the largest number of landing opportunities, and allow the smallest duration of in-orbit waits for the full range of possible shuttle missions for each of the seven crossranges considered for the shuttle orbiter These selected outside the CONUS worldwide support airfields are the same selected in reference 1

10 3 Landing Opportunities at Selected Worldwide Airfields

The landing opportunities provided by each of the selected worldwide airfields are illustrated in figure 12 and summarized in figure 13 for each mission profile analyzed and for each crossrange considered From each of the seven sets of airfields selected for each crossrange, a subset can be selected to provide the least possible MIW for each mission considered *

To provide worldwide landing support for a 100 n mi crossrange orbiter, a set of 18 airfields is required for the entire mission range These airfields are KSC, Moody AFB, Eglin AFB, New Orleans NAS, England AFB, Ellington AFB, Bergstrom AFB, Laughlin AFB, Darwin, N Djili, Hickam AFB, Nandi Intl , Lusaka Intl , Perth Intl , La Tontouta, Ramey AB, Kadena AB, and San Nicolas Is OLF For the 28 5^{o} inclination, 100 n mi altitude mission, a subset of five airfields provide a minimum MIW of four revolutions that occur 19 times in 114 revolutions These airfields are KSC, Laughlin AFB, Darwin, Lusaka Intl , and Kadena AB

For the 55^{o} inclination, 270 n mi altitude mission, a subset of six airfields provide a minimum MIW-of five revolutions that occur one time in 104 revolutions These airfields are KSC, Ellington AFB, Nandi Intl , Perth Intl , Kadena AB, and San Nicolas Is OLF. For the 90^{o} inclination, 400 n mi altitude mission, a subset of 15 airfields provide a minimum MIW of seven revolutions that occur three times in 95 revolutions These airfields are KSC, Moody AFB, Eglin AFB, New Orleans NAS, England AFB, Ellington AFB, Bergstrom AFB, Laughlin AFB, Darwin, N Djili, Hickam AFB, Nandi Intl , Perth Intl , La Tontouta, and Ramey AB

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*The data for this discussion were generated from the two computer programs--LTP and AIRAC

To provide worldwide landing support for a 150 n mi crossrange orbiter, a set of 14 airfields is required for the entire mission range These airfields are KSC, Eglin AFB, England AFB, Bergstrom AFB, Laughlin AFB, Darwin, N Djili, Hickam AFB, Nandi Intl , Lusaka Intl., Perth Intl , Ramey AB, Kadena AB, and San Nicolas Is. OLF For the 28 5° inclination, 100 n mi altitude mission, a subset of seven airfields provide a minimum MIW of four revolutions that occur three times in 114 revolutions These airfields are KSC, Laughlin AFB, Darwin, Hickam AFB, Nandi Intl , Ramey AB, and Kadena AB

For the 55° inclination, 270 n mi altitude mission, a subset of seven airfields provide a minimum MIW of four revolutions that occur one time in 100 revolutions These airfields are KSC, Bergstrom AFB, Laughlin AFB, N Djili, Hickam AFB, Nandi Intl , and Perth Intl For the 90° inclination, 400 n mi altitude mission, a subset of 12 airfields provide a minimum MIW of six revolutions that occur five times in 102 revolutions These airfields are KSC, Eglin AFB, England AFB, Bergstrom AFB, Laughlin AFB, Darwin, Hickam AFB, Lusaka Intl , Perth Intl , Ramey AB, Kadena AB, and San Nicolas Is OLF

To provide worldwide landing support for a 200 n mi crossrange orbiter, a set of 14 airfields is required for the entire mission range These airfields are KSC, Eglin AFB, Barksdale AFB, Laughlin AFB, Darwin, N Djili, Hickam AFB, Nandi Intl., Perth Intl , La Tontouta, Anderson AFB, Ramey AB, Kadena AB, and San Nicolas Is OLF. For the 28 5° inclination, 100 n mi altitude mission, a subset of six airfields provides a minimum MIW of three revolutions that occur 12 times in 114 revolutions These airfields are KSC, Laughlin AFB, Hickam AFB, Nandi Intl , Ramey AB, and Kadena AB

For the 55° inclination, 270 n mi. altitude mission, a subset of nine airfields provide a minimum MIW of three revolutions that occur two times in 100 revolutions These airfields are KSC, Barksdale AFB, Laughlin AFB, Hickam AFB, Nandi Intl , Perth Intl , Ramey AB, Kadena AB, and San Nicolas Is OLF For the 90° inclination, 400 n mi altitude mission, a subset of 10 airfields provide a minimum MIW of five revolutions that occur three times in 102 revolutions These airfields are KSC, Eglin AFB, Barksdale AFB, Laughlin AFB, Darwin, N Djili, Hickam AFB, La Tontouta, Andersen AFB, and Kadena AB

To provide worldwide landing support for a 250 n mi crossrange orbiter, a set of 15 airfields is required for the entire mission range. These airfields are KSC, Biggs AAF, Bergstrom AFB, Columbus AFB, Darwin, N Djili, Hickam AFB, Nandi Intl., Lusaka Intl , Perth Intl , La Tontouta, Andersen AFB, Ramey AB, Kadena AB, and San Nicolas Is OLF For the 28 5° inclination, 100 n. mi altitude mission, a subset of eight airfields provide a minimum MIW of two revolutions

that occur 20 times in 114 revolutions These airfields are KSC, Biggs AAF, Darwin, Hickam AFB, Nandi Intl , Andersen AFB, Ramey AB, and Kadena AB

For the 55° inclination, 270 n mi altitude mission, a subset of eight airfields provides a minimum MIW of two revolutions that occur 28 times in 100 revolutions These airfields are KSC, Biggs AAF, Bergstrom AFB, Hickam AFB, Nandi Intl , Perth Intl , Kadena AB, and San Nicolas Is OLF For the 90° inclination, 400 n mi altitude mission, a subset of all 15 airfields provides a minimum MIW of three revolutions that occur one time in 102 revolutions These airfields are the same 15 listed for the entire mission range

To provide worldwide landing support for a 500 n mi crossrange orbiter, a set of 13 airfields is required for the entire mission range These airfields are KSC, Bergstrom AFB, Darwin, N Djili, Hickam AFB, Nandi Intl , Lusaka Intl , Perth Intl , La Tontouta, Andersen AFB, Ramey AB, Kadena AB, and San Nicolas Is OLF For the 28 5° inclination, 100 n mi altitude mission, a subset of nine airfields provides a minimum MIW of one revolution These airfields are KSC, Bergstrom AFB, N Djili, Hickam AFB, Nandi Intl , La Tontouta, Andersen AFB, Ramey AB, and Kadena AB

For the 55° inclination, 270 n mi altitude mission, a subset of seven airfields provides a minimum MIW of two revolutions that occur 32 times in 115 revolutions These airfields are KSC, Bergstrom AFB, Darwin, N Djili, Hickam AFB, Nandi Intl , and San Nicolas Is OLF For the 90° inclination, 400 n mi altitude mission, a subset of eight airfields provides a minimum MIW of two revolutions that occur 34 times in 102 revolutions These airfields are KSC, Bergstrom AFB, Darwin, N Djili, Nandi Intl , Lusaka Intl , Perth Intl , and La Tontouta

To provide worldwide landing support for a 1100 n mi crossrange orbiter, a set of 10 airfields is required for the entire mission range These airfields are KSC, Bergstrom AFB, N Djili, Hickam AFB, Nandi Intl , Lusaka Intl , Perth Intl , La Tontouta, Andersen AFB, and San Nicolas Is OLF For the 28 5° inclination, 100 n mi altitude mission, a subset of five airfields provides a minimum MIW of one revolution These airfields are KSC, Bergstrom AFB, Hickam AFB, Nandi Intl , and Andersen AFB. For the 55° inclination, 270 n mi altitude mission, a subset of six airfields provides a minimum MIW of one revolution These airfields are KSC, Bergstrom AFB, N Djili, Hickam AFB, Perth Intl., and Andersen AFB For the 90° inclination, 400 n mi altitude mission, a subset of eight airfields provides a minimum MIW of one revolution These airfields are KSC, Bergstrom AFB, Hickam AB, Lusaka Intl , Perth Intl , La Tontouta, Andersen AFB, and San Nicolas Is OLF

To provide worldwide landing support for a 1500 n mi crossrange orbiter, a set of nine airfields is required for the entire mission range These airfields are KSC, Darwin, N Djili, Hickam AFB, Nandi Intl , Lusaka Intl , Andersen AFB, Kadena AB, and San Nicolas Is OLF For the 28 5° inclination, 100 n mi altitude mission, a subset of three airfields provides a minimum MIW of one revolution These airfields are KSC, N Djili, and Nandi Intl For the 55° inclination, 270 n mi altitude mission, a subset of three airfields provides a minimum MIW of one revolution These airfields are KSC, Hickam AFB, and Kadena AB For the 90° inclination, 400 n mi altitude mission, a subset of six airfields provides a minimum MIW of one revolution These airfields are KSC, Darwin, Nandi Intl , Lusaka Intl , Andersen AFB, and San Nicolas Is OLF

In general, the above discussion presents the subsets of airfields that provide the minimum MIW's possible Various other combinations of these worldwide support airfields offer other MIW's which can be determined by adding up the coverages of the various airfields illustrated in figure 12 MIW's greater than two revolutions or so may be acceptable as an operating standard as the shuttle program becomes better defined The above subsets of airfields were chosen to provide a comparison of crossranges, MIW's and numbers of worldwide support airfields These subsets also provide the best coverage possible using the best airfields available for each case analyzed

11 0 OPTIMIZED CROSSRANGE, NUMBER OF AIRFIELDS, AND IN-ORBIT WAIT

Considering all of the data thus far developed on crossranges, MIW's, and number of airfields, it is possible to determine an optimized combination of crossrange, in-orbit wait, and number of support airfields To determine the optimum arrangement, both MIW's and number of airfields were plotted against hypersonic crossrange (fig 14) to see if any significant areas in the curves occur The curves were based on discrete data points, and as such, straight-line interpolation between points was used to illustrate that the data are not continuous The MIW's plotted were the largest ones from those of the three mission profiles analyzed for a specific crossrange The number of support airfields plotted were the total number of individual airfields required for all three mission profiles (the entire mission range) The plots were made in two parts--one using the CONUS airfields only and another using the worldwide airfields The curves for number of airfield vs crossrange were plotted and then fitted over the plots for MIW vs crossrange as closely as possible This illustrates the significant turning points of the plots

These overlayed plots show that by using worldwide support airfields, the MIW increases greatly for crossranges less than 250 n mi and that the number of airfields needed increases rapidly for crossranges less than 150 n mi Using only CONUS airfields, the MIW increases rapidly below a 200 n mi crossrange and airfield numbers increase rapidly below a 200 n mi crossrange These plots, then, show that the optimum minimum crossrange, minimum MIW, and minimum number of support airfields occur at a crossrange of about 200 n mi with about 14 worldwide support airfields and a worst case MIW of five revolutions Greater hypersonic crossrange requires slightly fewer airfields and provides less MIW's In general, crossranges less than 200 n mi should not be considered if an attempt is made to provide an optimum landing support scheme for the shuttle orbiter

12 0 RECOMMENDATIONS

From the cases discussed, it is emphasized that if crossranges of less than 200 n mi are designed for the shuttle orbiter, the impact of using additional airfields for support and accepting longer in-orbit waits must be considered The cost of adding runway length and adding required ground navigation aids at these additional airfields also should be factored into the overall program design The same general recommendations given in reference 1 are also applicable to this paper, that is, it is recommended that the primary end-of-mission airfield be the planned landing site and would require the most ground support capability It is also recommended that an end-of-first-revolution airfield be provided in the CONUS and that this airfield would require ground support somewhat less than that at the end-of-mission airfield A once-per-day landing opportunity within the CONUS is desired, and these airfields should require no premission support--only after-the-fact ground support should be required Emergency landing opportunities throughout the world should be provided as often as necessary Only after-the-fact ground support should be provided at these outside the CONUS airfields

It is further recommended that the shuttle orbiter be designed to land on runway lengths not in excess of 10,000 ft, and runways with support strengths for not more than about 100 psi and an equivalent single-wheel loading of not more than about 50,000 lb All of these recommendations are based on the use of the best available airfields

13 0 REFERENCES

1 Ferguson, Jonny E , Richeson, George L , and Pettit, Millard C Landing Airfields Selection With Implicit Designs and Operations for Shuttle Orbiters, Landing and Recovery Division internal note MSC-02438, National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas, May 15, 1970

2 Ferguson, Jonny E Analysis Optimized Land-Landing Sites, NASA Program Apollo Working Paper MSC-00159, National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas, September 30, 1969

TABLE I - DISTRIBUTION OF FREE WORLD AIRFIELDS

Runway lengths, ft	Location	Number of airfields			
		Concrete	Asphalt	Other	Total
≥8,000	Inside U.S A	133	184	6	323
	Free world outside U S A	288	475	68	831
	Total free world	421	659	74	1154
≥10,000	Inside U S.A.	81	59	1	141
	Free world outside U.S.A	99	127	34	260
	Total free world	180	186	35	401
≥12,000	Inside U.S A.	34	19	0	53
	Free world outside U S A.	18	27	14	59
	Total free world	52	46	14	112
≥14,000	Inside U S.A	2	2	0	4
	Free world outside U.S.A.	1	3	7	11
	Total free world	3	5	7	15

Source--Department of the Air Force, Headquarters, Aeronautical Chart and Information Center, Second and Arsenal, St. Louis, Missouri Printout of Selected Airfields, November 5, 1969.

TABLE II - MILITARY AIRFIELDS WITHIN THE CONTINENTAL UNITED STATES HAVING RUNWAY LENGTHS OF 10,000 FEET OR GREATER OR EXTENDABLE TO 10,000 FEET

State	Name	Lat , Long , deg-min	Elevation ft	Runway Length, ft	Runway Construction	Runway Strength (a)	Navigation Aids
Alabama	Brookley AFB	30-37N, 88-03W	26	9,600	Concrete	79 psi SWL-79K lb	GCA, DF, RBN, VORTAC
Alabama	Craig AFB	32-21N, 86-59W	166	8,000	Asphalt	290 psi SWL-21K lb	ILS, GCA, DF, RBN, TACAN, VOR
Arizona	Davis Monthan AFB	32-10N, 110-53W	2705	13,645	Concrete	180 psi SWL-44K lb	TACAN, LOM, ILS, ASR, PAR
Arizona	Luke AFB	33-33N, 112-23W	1101	10,000	Asphalt	130 psi SWL-46K lb	TACAN, RBN, ASR, PAR
Arizona	Williams AFB	33-18N, 111-39W	1385	10,400	Concrete	290 psi SWL-17K lb	VORTAC, ILS, ASR, PAR
Arizona	Yuma MCAS/Yuma Intl	32-39N, 114-36W	213	13,300	Concrete	T-225K lb SWL-62K lb	TACAN, VORTAC, RBN, D/F, GCA
California	El Toro MCAS	33-40N, 117-44W	383	10,000	Asphalt	98 psi SWL-40K lb	VOR, TACAN, RBN, UHF/DF, PAR, ASR, GCA, ILS
California	March AFB	33-54N, 117-15W	1533	13,300	Concrete	285 psi SWL-75K lb	VOR, TACAN, ILS, PAR
California	Mirimar NAS	32-52N, 117-09W	477	12,000	Concrete	143 psi SWL-55K lb	TACAN, RBN, VHF/UHF/DF, ASR, PAR
California	San Nicolas Is OLF	33-14N, 119-27W	504	10,000	Asphalt	124 psi SWL-36K lb	TACAN, RBN, ASR, PAR, GCA
Florida	Cape Kennedy AFS Skid Strip	28-28N, 80-34W	9	10,000	Asphalt	180 psi SWL-38K lb	VFR daylight operations only
Florida	Cecil Field NAS	30-13N, 81-52W	80	12,500	Asphalt	180 psi SWL-50K lb	VORW, TACAN, RBN, VHF/DF, ASR
Florida	Eglin AFB	30-29N, 86-32W	85	12,000	Asphalt	285 psi SWL-75K lb	VOR, TACAN, RBN, LMM, ILS, ASR, PAR

(a) - Runway surface strength may be designated by (1) T - weight exerted on runway by twin or tandem wheel landing gear in pounds, (2) SWL - equivalent single-wheel loading or single isolated wheel loading of landing gear in pounds, or (3) maximum pressure runway will support in pounds per square inch

TABLE II - CONTINUED

State	Name	Lat , Long , deg-min	Elevation ft	Runway Length, ft	Runway Construction	Runway Strength (a)	Navigation Aids
Florida	Homestead AFB	25-29N, 80-23W	7	11,200	Asphalt	285 psi SWL-75K lb	VOR, TACAN, RBN, ILS, ASR, PAR
Florida	Key West NAS	24-35N, 81-41W	6	10,000	Asphalt	130 psi SWL-50K lb	TACAN, RBN, ASR, PAR
Florida	MacDill AFB	22-51N, 82-31W	13	11,420	Asphalt	180 psi SWL-44K lb	ILS, TACAN, RBN, ASR, PAR
Florida	McCoy AFB	28-26N, 81-19W	96	12,002	Concrete	285 psi SWL-75K lb	TACAN, RBN, ASR, PAR, ILS, VOR, VORTAC, GCA
Florida	Tyndall AFB	30-04N, 85-35W	18	10,000	Concrete	143 psi SWL-37K lb	TACAN, ILS, ASR, PAR
Florida	Pensacola NAS	30-21N, 87-19W	30	8,000	Asphalt	124 psi SWL-54K lb	ILS, GCA, DF, RBN, TACAN
Georgia	Glynco NAS	31-15N, 81-28W	25	8,000	Asphalt	95 psi SWL-46K lb	GCA, DF, RBN, TACAN
Georgia	Moody AFB	30-58N, 83-11W	233	8,000	Asphalt	750 psi SWL-65K lb	ILS, GCA, DF, TACAN, VOR
Georgia	Albany NAS	31-36N, 84-05W	212	12,050	Asphalt	285 psi SWL-75K lb	TACAN, RBN, ASR, PAR
Georgia	Dobbins AFB/ Atlanta NAS	33-55N, 84-31W	1068	10,000	Concrete	285 psi SWL-75 K lb	RBN, BVORTAC, ASR, PAR
Georgia	Hunter AAF	32-01N, 81-09W	42	11,375	Asphalt	650 psi SWL-65K lb	LOM, ILS, ASR, PAR
Georgia	Robins AFB	32-28N, 83-36W	294	12,000	Asphalt	285 psi SWL-75K lb	RBN, LOM, UHF/DF, BVORTAC, ILS, ASR, PAR
Louisiana	Barksdale AFB	32-30N, 93-40W	167	11,754	Concrete	285 psi SWL-75K lb	TACAN, ILS, ASR, PAR
Louisiana	England AFB	31-19N, 92-33W	89	9,350	Concrete	180 psi SWL-44K lb	GCA, DF, RBN, VORTAC, TACAN

(a) - Runway surface strength may be designated by (1) T - weight exerted on runway by twin or tandem wheel landing gear in pounds, (2) SWL - equivalent single-wheel loading or single isolated wheel loading of landing gear in pounds, or (3) maximum pressure runway will support in pounds per square inch

TABLE II - CONTINUED

State	Name	Lat , Long , deg-min	Elevation, ft	Runway Length, ft	Runway Construction	Runway Strength (a)	Navigation Aids
Louisiana	New Orleans NAS	29-50N, 90-01W	3	8,000	Asphalt	79 psi SWL-59K lb	GCA, DF, RBN, TACAN
Mississippi	Meridian NAAS	32-33N, 88-33W	317	8,000	Concrete	285 psi SWL-82K lb	GCA, DF, RBN, TACAN
Mississippi	Columbus AFB	33-39N, 88-27W	214	12,000	Concrete	230 psi SWL-79K lb	ILS, ASR, PAR
New Mexico	Holloman AFB	32-51N, 106-06W	4094	12,228	Asphalt	T-155K lb	VOR, TACAN, RBN, ASR, PAR
South Carolina	Beaufort MCAS	32-29N, 80-43W	38	12,200	Concrete	79 psi SWL-50K lb	TACAN, RBN, UHF/DF, ASR, PAR
South Carolina	Shaw AFB	33-58N, 80-29W	252	10,000	Concrete	183 psi SWL-45K lb	TACAN, RBN, ILS, ASR, PAR
Texas	Bergstrom AFB	30-12N, 97-40W	541	12,250	Concrete	100 psi SWL-77K lb	TACAN, RBN, BVORTAC, VOR, ILS, ASR, PAR
Texas	Biggs AAF	31-51N, 106-23W	3947	13,572	Concrete	285 psi SWL-75K lb	BVOR, ASR
Texas	Carswell AFB	32-46N, 97-26W	650	12,000	Concrete	750 psi SWL-65K lb	TACAN, VOR, ILS, ASR, PAR
Texas	Dyess AFB	32-25N, 99-51W	1789	13,500	Concrete	285 psi SWL-75K lb	TACAN, RBN, BVORTAC, ILS, ASR, PAR
Texas	Kelley AFB	29-23N, 98-35W	690	11,500	Concrete	285 psi SWL-75K lb	VOR, TACAN, UHF/DF, ILS, ASR, PAR
Texas	Reese AFB	33-36N, 102-03W	3338	10,500	Concrete	124 psi SWL-25K lb	TACAN, UHF/DF, BVORTAC, ASR, PAR

(a) - Runway surface strength may be designated by (1) T - weight exerted on runway by twin or tandem wheel landing gear in pounds, (2) SWL - equivalent single-wheel loading or single isolated wheel loading of landing gear in pounds, or (3) maximum pressure runway will support in pounds per square inch

TABLE II - CONCLUDED

State	Name	Lat , Long , deg-min	Elevation, ft	Runway			Navigation Aids
				Length, ft	Construction	Strength (a)	
Texas	Sheppard AFB	33-59N, 98-30W	1015	13,100	Concrete	285 psi SWL-75K lb	TACAN, VHF/UHF/DF, ILS, ASR, PAR
Texas	Webb AFB	32-14N, 101-31W	2561	9,150	Asphalt	143 psi SWL-37K lb	ILS, GCA, RBN, VORTAC, TACAN, VOR
Texas	Perrin AFB	33-43N, 96-40W	753	9,000	Asphalt	T-80K lb SWL-25K lb 300 psi	ILS, GCA, DF, RBN, VORTAC, TACAN, VOR
Texas	Ellington AFB	29-37N, 95-10W	40	9,000	Concrete	SWL-40K lb 650 psi	GCA, TACAN, VOR
Texas	Chase Field NAS	28-22N, 97-39W	186	8,000	Asphalt	95 psi SWL-50K lb	GCA, DF, RBN, TACAN
Texas	Laughlin AFB	29-22N, 100-47W	1081	8,857	Asphalt	95 psi SWL-43K lb	ILS, GCA, DF, RBN, VORTAC, TACAN, VOR
Texas	Randolph AFB	29-32N, 98-17W	761	8,350	Concrete	77 psi SWL-28K lb	ILS, GCA, TACAN
Texas	Kingsville NAS	27-29N, 97-48W	50	8,000	Concrete	SWL-50K lb 150 psi	GCA, DF, RBN, TACAN
Texas	Laredo AFB	27-33N, 99-28W	508	8,200	Concrete	77 psi SWL-28K lb	ILS, GCA, DF, VORTAC, TACAN

(a) - Runway surface strength may be designated by (1) T - weight exerted on runway by twin or tandem wheel landing gear in pounds, (2) SWL - equivalent single-wheel loading or single isolated wheel loading of landing gear in pounds, or (3) maximum pressure runway will support in pounds per square inch

Sources--Department of the Air Force, Headquarters, Aeronautical Chart and Information Center, Second and Arsenal, St Louis, Missouri Printout of Selected Airfields, November 5, 1969
--The Aeronautical Chart and Information Center, United States Air Force, IFR - Supplement - United States, DOD Flight Information Publication, St Louis, Missouri, Jan 8, 1970
--Hay, Delynn R Airfield Characteristics For Airfield Pavement Design and Evaluation, Technical Report No AFWL-TR-69-54, Air Force Weapons Laboratory, Air Force Systems Command, Kirtland Air Force Base, New Mexico, October 1969

TABLE III - AIRFIELDS SELECTED OUTSIDE THE CONTINENTAL UNITED STATES
HAVING RUNWAY LENGTHS OF 10,000 FEET OR GREATER

Country	Name	Lat, Long, deg-min	Elevation, ft	Runway			Navigation Aids
				Length, ft	Construction	Strength (a)	
Australia	Darwin	12-25S, 130-52E	104	11,000	Asphalt	707, DC-8	VHF, VOR, ILS, RBN, DME, Approach Control
Australia	Perth Intl	31-56S, 115-58E	69	10,300	Asphalt	C-135, 155 psi, SWL-57K lb	RBN, VOR, ILS, VHF/DF, Approach Control
Brazil	Galeao	22-49S, 43-15W	20	10,827	Concrete	C-135, 143 psi SWL-37K lb	VOR, ILS, RBN, ASR, Approach Control
Congo	N Djili	4-23S, 15-27E	1014	15,420	Concrete	140 psi SWL-99K lb	UHF/VHF/DF, ILS
Fiji Is	Nandi Intl	17-46S, 177-27E	63	10,500	Concrete	190 psi SWL-65K lb	RBN, VOR, ILS, VHF/DF, Approach Control
Guam	Agana NAS	13-29N, 144-47E	298	10,000	Asphalt	155 psi SWL-46K lb	GCA, ASR, PAR, RBN, VOR, TACAN, UHF/VHF/DF, Approach Control
Guam	Andersen AFB	13-35N, 144-55E	624	11,200	Concrete	285 psi SWL-110K lb	ILS, ASR, PAR, VOR, RBN, GCA, Approach Control
Hawaii	Honolulu Intl / Hickam AFB	21-20N, 157-55W	13	12,371	Asphalt	285 psi SWL-110K lb	VORTAC, RBN, UHF/VHF/DF, ILS, ASR
India	Bombay/Santa Cruz	19-05N, 72-52E	35	11,005	Concrete	160 psi SWL-52K lb	ILS, RBN, VOR, VHF/DF, Approach Control
India	Calcutta	22-39N, 88-27E	15	10,500	Concrete	155 psi SWL-57K lb	ILS, VOR, RBN, Approach Control

(a) - Runway surface strength may be designated by (1) SWL - equivalent single-wheel loading or single isolated wheel loading of landing gear in pounds, (2) maximum pressure runway will support in pounds per square inch, or (3) heaviest aircraft known to land without causing surface damage

TABLE III--CONTINUED

Country	Name	Lat , Long , deg-min	Elevation, ft	Runway			Navigation Aids
				Length, ft	Construction	Strength (a)	
India	Nagpur	21-05N, 79-03E	1020	10,500	Concrete	105 psi SWL-36K lb	ILS, VOR, RBN, DF, Approach Control
Guinea	Conakry	9-35N, 13-37W	72	10,827	Concrete	330K lb gross	PAR, RBN, VHF/DF, VOR, Approach Control
Malaysia Federation	Kuala Lampur Intl	3-08N, 101-33E	89	11,400	Asphalt	155 psi SWL-56K lb	ILS, RBN, Approach Control
New Caledonia	La Tontouta	22-01S, 166-13E	52	10,663	Asphalt	155 psi SWL-46K lb	ILS, VOR, RBN
Peru	Jorge Chavez Intl	12-02S, 77-07W	105	11,500	Concrete	KC-135,155 psi SWL-40K lb	ILS, Approach Control, VOR, RBN
Phillipines	Clark AFB	15-11N, 120-33E	478	10,500	Concrete	100 psi SWL-106K lb	ILS, ASR, PAR, GCA, VOR, TACAN, UHF/DF, Approach Control
Phillipines	Manila Intl	14-31N, 121-01E	74	11,000	Asphalt	SWL-50K lb	ILS, VOR, RBN, Approach Control
W Pakistan	Karachi Civil	24-54N, 67-09E	95	10,500	Concrete	155 psi SWL-57K lb	ILS, VOR, RBN, Approach Control
Puerto Rico	Puerto Rico Intl	18-27N, 66-00W	9	10,000	Concrete	160 psi SWL-52K lb	ASR, UHF/DF, VORTAC, RBN, Approach Control
Puerto Rico	Ramey AFB	18-30N, 67-08W	30	11,700	Concrete	285 psi SWL-108K lb	ILS, GCA, UHF/DF, VOR, RBN, TACAN, Approach Control
Puerto Rico	Roosevelt Roads NS	18-15N, 65-38W	39	11,000	Concrete	150 psi SWL-122K lb	GCA, TACAN, RBN, UHF/VHF/DF, Approach Control

(a) - Runway surface strength may be designated by (1) SWL - equivalent single-wheel loading or single isolated wheel loading of landing gear in pounds, (2) maximum pressure runway will support in pounds per square inch, or (3) heaviest aircraft known to land without causing surface damage

TABLE III--CONTINUED

Country	Name	Lat , Long , deg-min	Elevation, ft	Runway			Navigation Aids
				Length, ft	Construction	Strength (a)	
Ryukyu Is	Kadena AB	26-21N, 127-46E	142	12,100	Concrete	285 psi SWL-155K lb	ILS, ASR, PAR, VOR, RBN, TACAN, Approach Control
Zambia	Lusaka Intl	15-20S, 28-27E	3779	13,000	Asphalt	270 psi SWL-106K lb	ILS, ASR, VHF/DF, VOR, DME, Approach Control
Society Is	Faaa	17-33S, 149-36W	6	11,204	Asphalt	155 psi SWL-46K lb	ILS, VOR, RBN, VHF/DF, Approach Control
Thailand	Bangkok Intl	13-55N, 100-37E	12	10,500	Concrete	190 psi SWL-65K lb	ILS, GCA, TACAN, VOR, RBN, VORTAC, Approach Control
Thailand	Udorn USAF	17-23N, 102-48E	585	10,000	Concrete	190 psi SWL-65K lb	GCA, TACAN, RBN
Taiwan	Chia I	23-28N, 120-23E	82	10,006	Concrete	190 psi SWL-65K lb	GCA, RBN, TACAN, DF, Approach Control
Taiwan	Ching Chuan Kang	24-16N, 120-37E	663	12,000	Concrete	190 psi SWL-65K lb	ILS, GCA, VOR, RBN, TACAN, UHF/DF, Approach Control
Taiwan	Hsin Cha	24-49N, 120-56E	25	10,012	Concrete	76 psi SWL-60K lb	ASR, PAR, TACAN, RBN
Taiwan	Tai Nan	22-37N, 120-12E	--	10,004	Concrete	76 psi SWL-60K lb	GCA, TACAN, RBN, VOR, UHF/DF, Approach Control
Taiwan	T'Ao Yuan	25-03N, 121-14E	--	10,005	Concrete	76 psi SWL-60K lb	ASR, PAR, TACAN, RBN, UHF/DF

(a) - Runway surface strength may be designated by (1) SWL - equivalent single-wheel loading or single isolated wheel loading of landing gear in pounds, (2) maximum pressure runway will support in pounds per square inch, or (3) heaviest aircraft known to land without causing surface damage

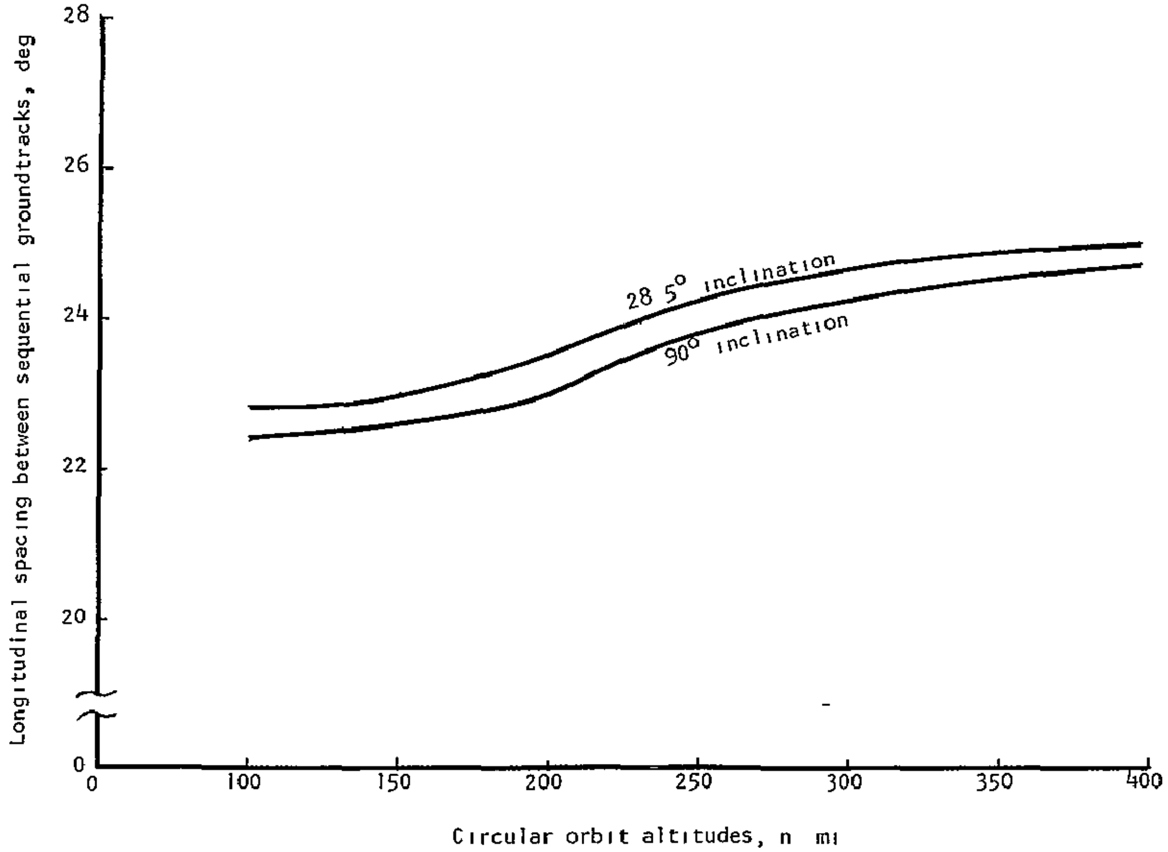
TABLE III--CONCLUDED

Country	Name	Lat , Long , deg-min	Elevation, ft	Runway			Navigation Aids
				Length, ft	Construction	Strength (a)	
Venezuela	El Libertador	10-11N, 67-33W	1450	10,224	Concrete	270 psi SWL-106K lb	ASR, VHF/DF
South Vietnam	Cam Ranh Bay	11-59N, 109-13E	31	10,000	Concrete	190 psi SWL-65K lb	GCA, TACAN, RBN, Approach Control
South Vietnam	Chu Lai AB	15-25N, 108-42E	25	10,000	Concrete	C-141 180 psi SWL-44K lb	GCA, TACAN, Approach Control
South Vietnam	Phan Rang	11-37N, 108-57E	102	10,000	Concrete	C-141, 180 psi SWL-44K lb	GCA, TACAN, RBN
South Vietnam	Da Nang	16-03N, 108-12E	30	10,000	Asphalt	190 psi SWL-65K lb	ASR, PAR, VOR, RBN, TACAN, Approach Control
South Vietnam	Bien Hoa	10-58N, 106-49E	36	10,000	Concrete	C-141 180 psi SWL-44K lb	PAR, ASR, RBN, TACAN
South Vietnam	Phu Cat	13-57N, 109-02E	101	10,000	Concrete	190 psi SWL-65K lb	ASR, PAR, RBN, TACAN
South Vietnam	Tan Son Nhut	10-49N, 106-39E	33	10,000	Concrete	C-141,180 psi SWL-44K lb	ILS, ASR, PAR, RBN, TACAN

(a) - Runway surface strength may be designated by (1) SWL - equivalent single-wheel loading or single isolated wheel loading of landing gear in pounds, (2) maximum pressure runway will support in pounds per square inch, or (3) heaviest aircraft known to land without causing surface damage

Sources--Department of the Air Force, Headquarters, Aeronautical Chart and Information Center, Second and Arsenal, St Louis, Missouri Printout of Selected Airfields, November 5, 1969

--Hay, Delynn R Airfields Characteristics for Airfield Pavement Design and Evaluation, Technical Report No AFWL-TR-69-54, Air Force Weapons Laboratory, Air Force Systems Command Kirtland Air Force Base New Mexico, October 1969



Note Information for this graph was obtained from ref 2

Figure 1 - Spacing between sequential groundtracks

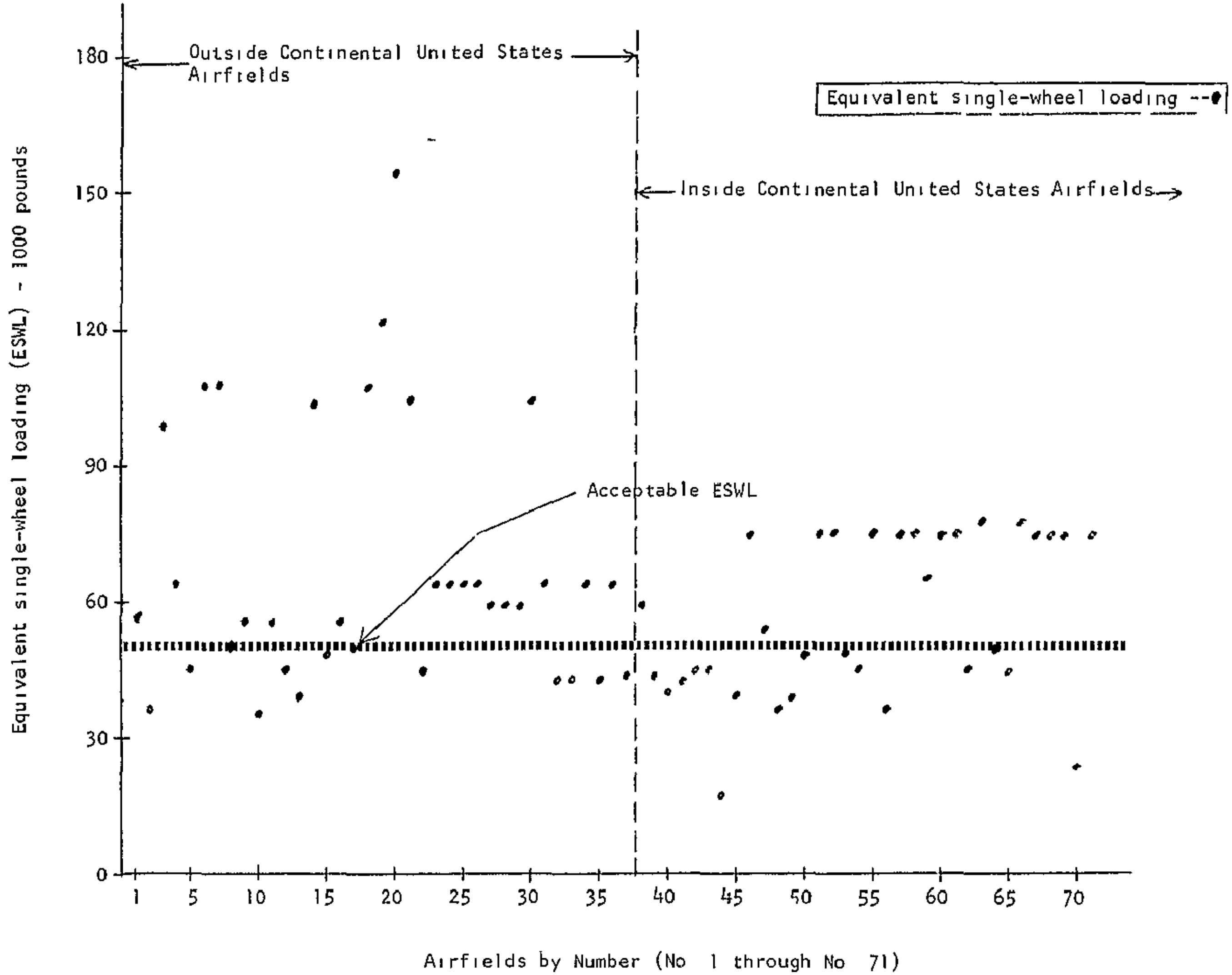


Fig 2 - Runway equivalent single-wheel loading comparisons

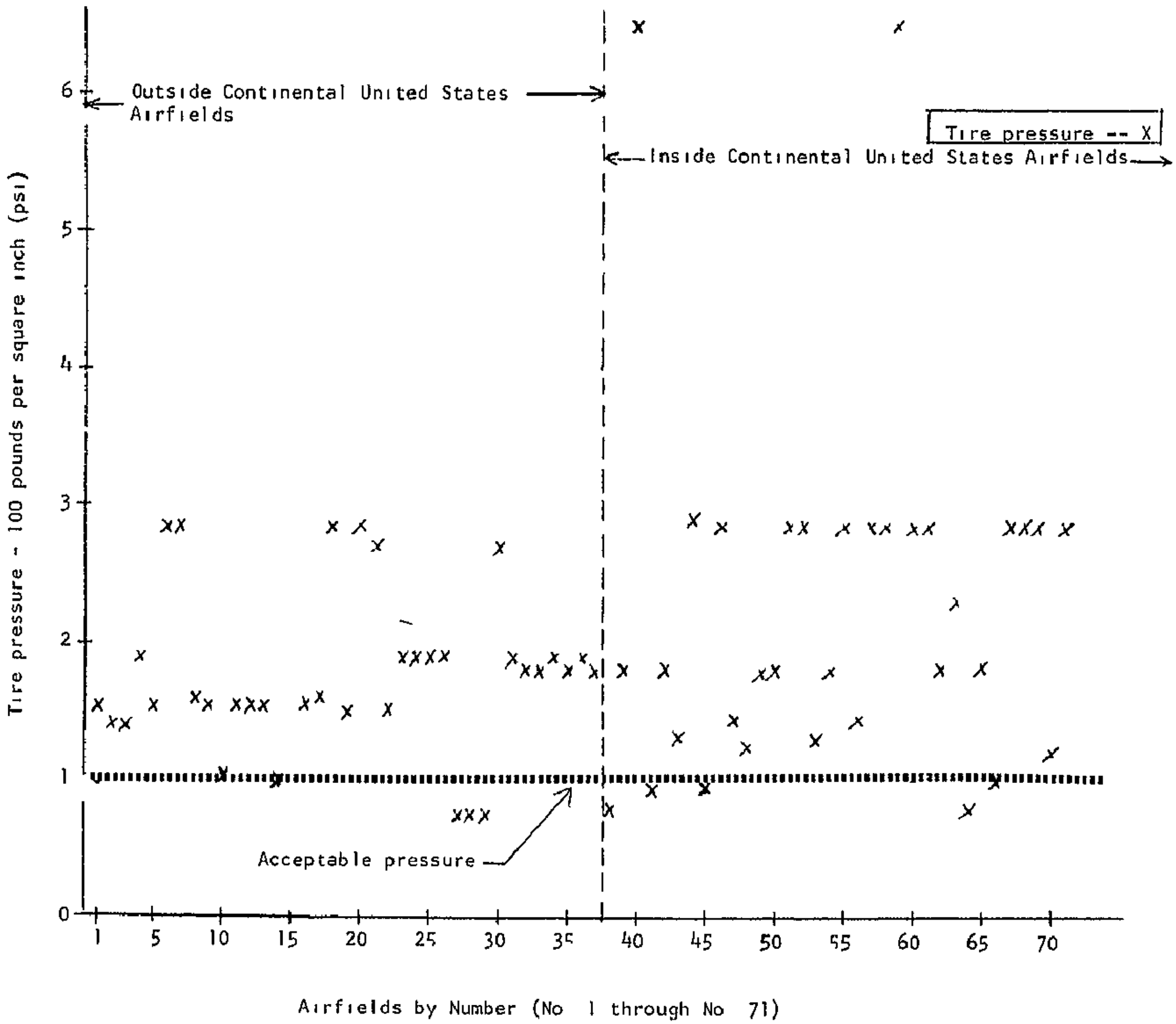


Fig 3 - Runway pressure strength

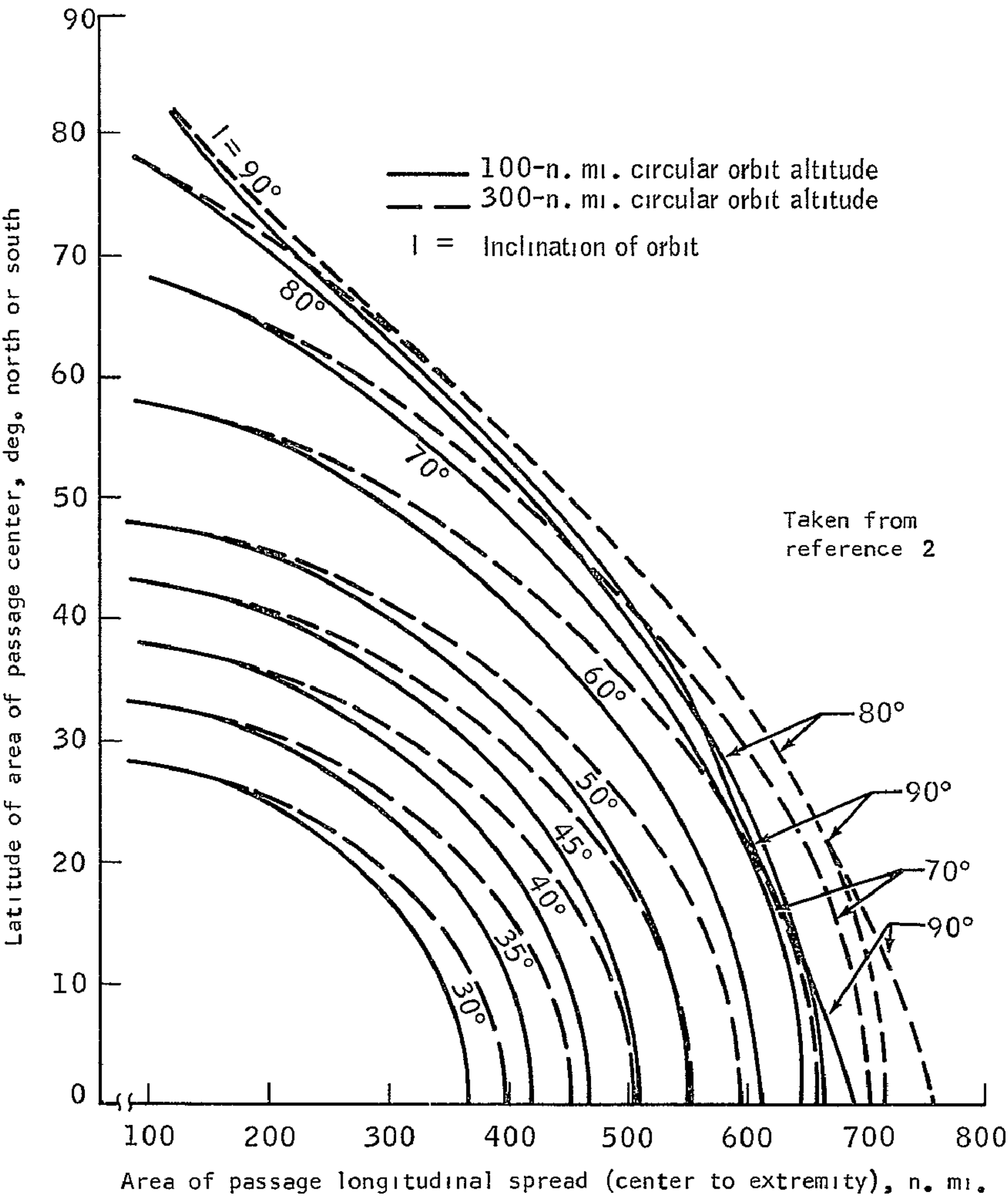


Figure 4 - Area of passage sizing

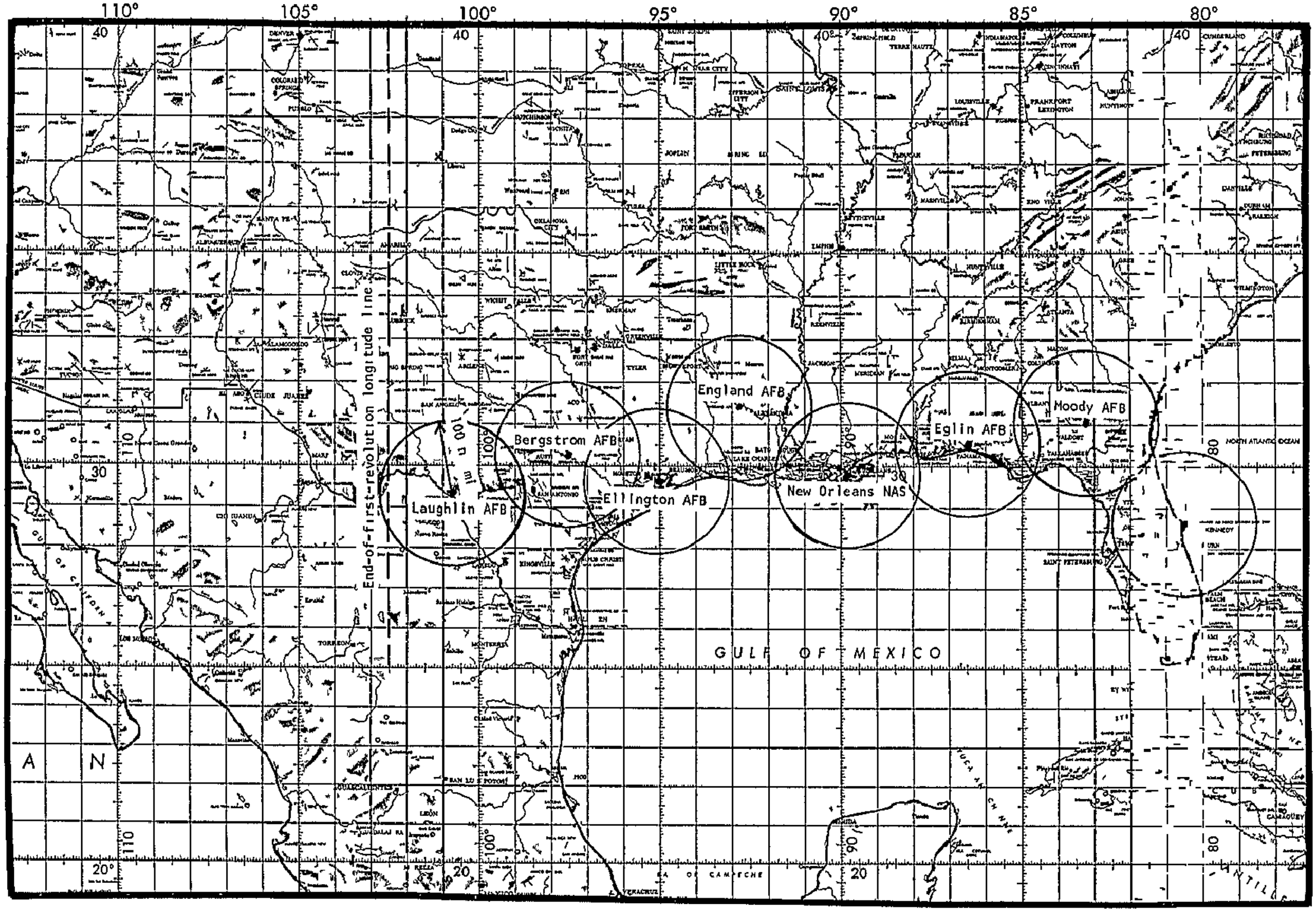


Figure 5 - Continental United States airfields to support a 100 n mi crossrange shuttle orbiter

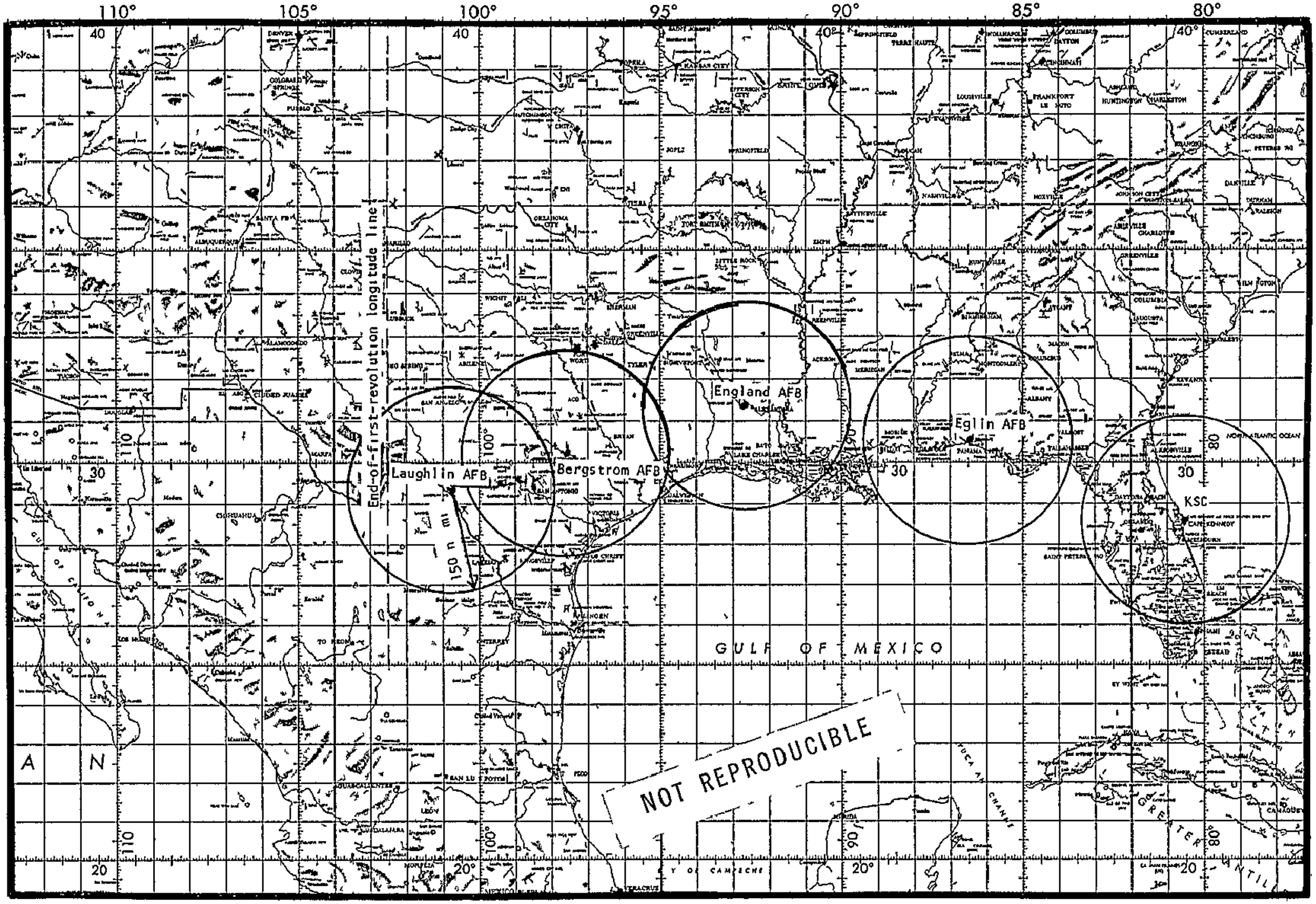


Figure 6 - Continental United States airfields to support a 150 n mi crossrange shuttle orbiter

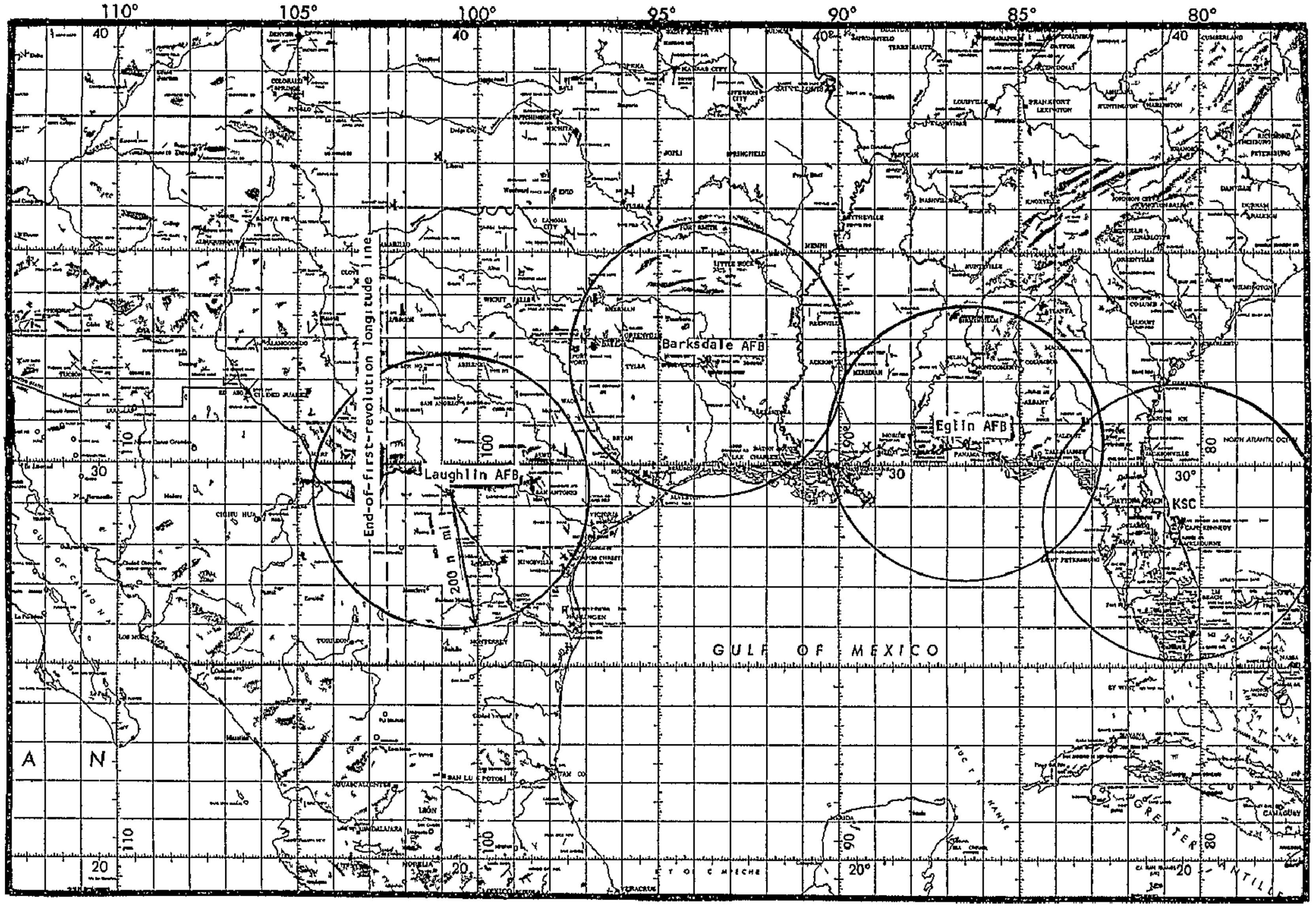


Figure 7 - Continental United States airfields to support a 200 n mi crossrange shuttle orbiter

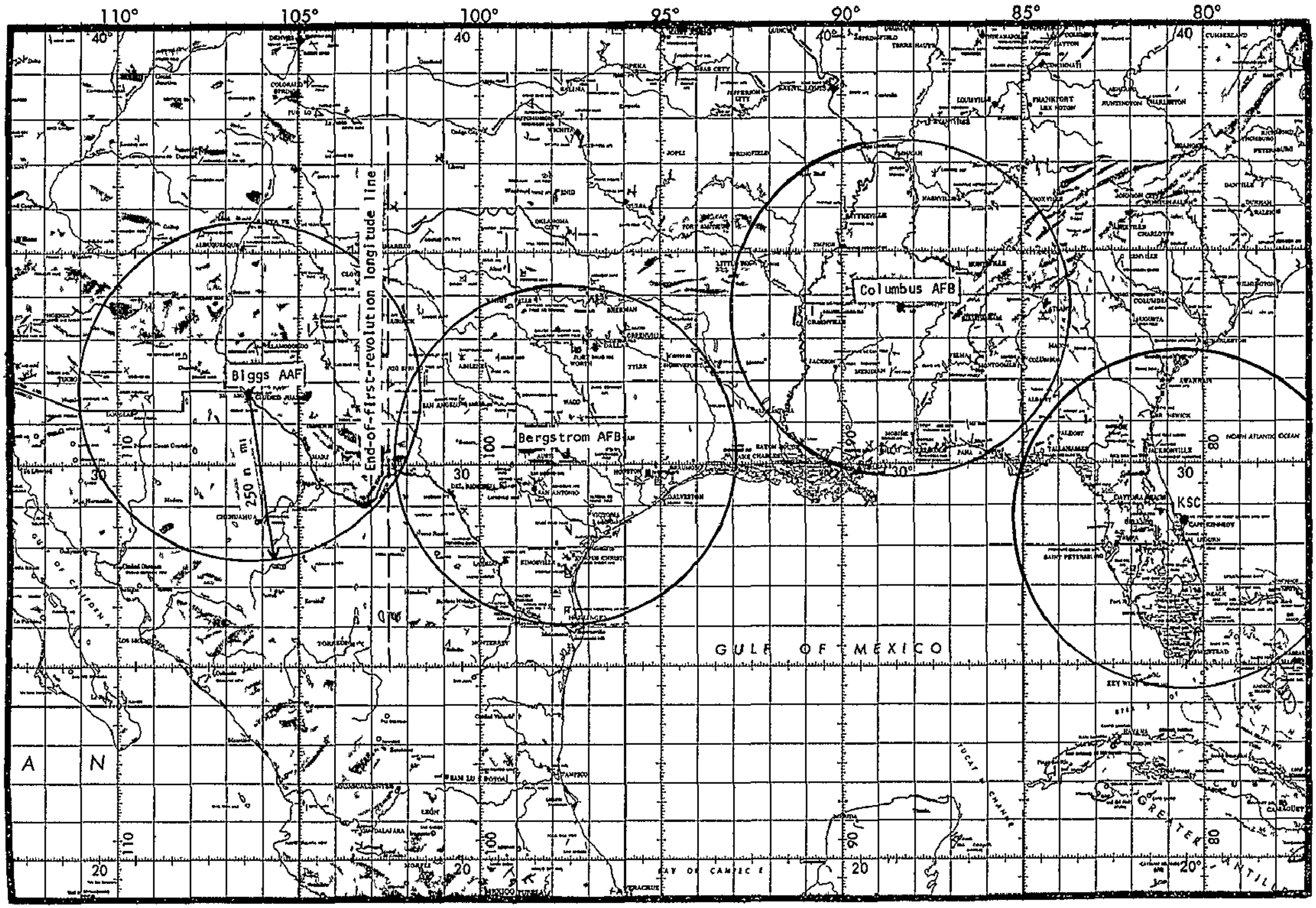


Figure 8 - Continental United States airfields to support a 250 n mi crossrange shuttle orbiter

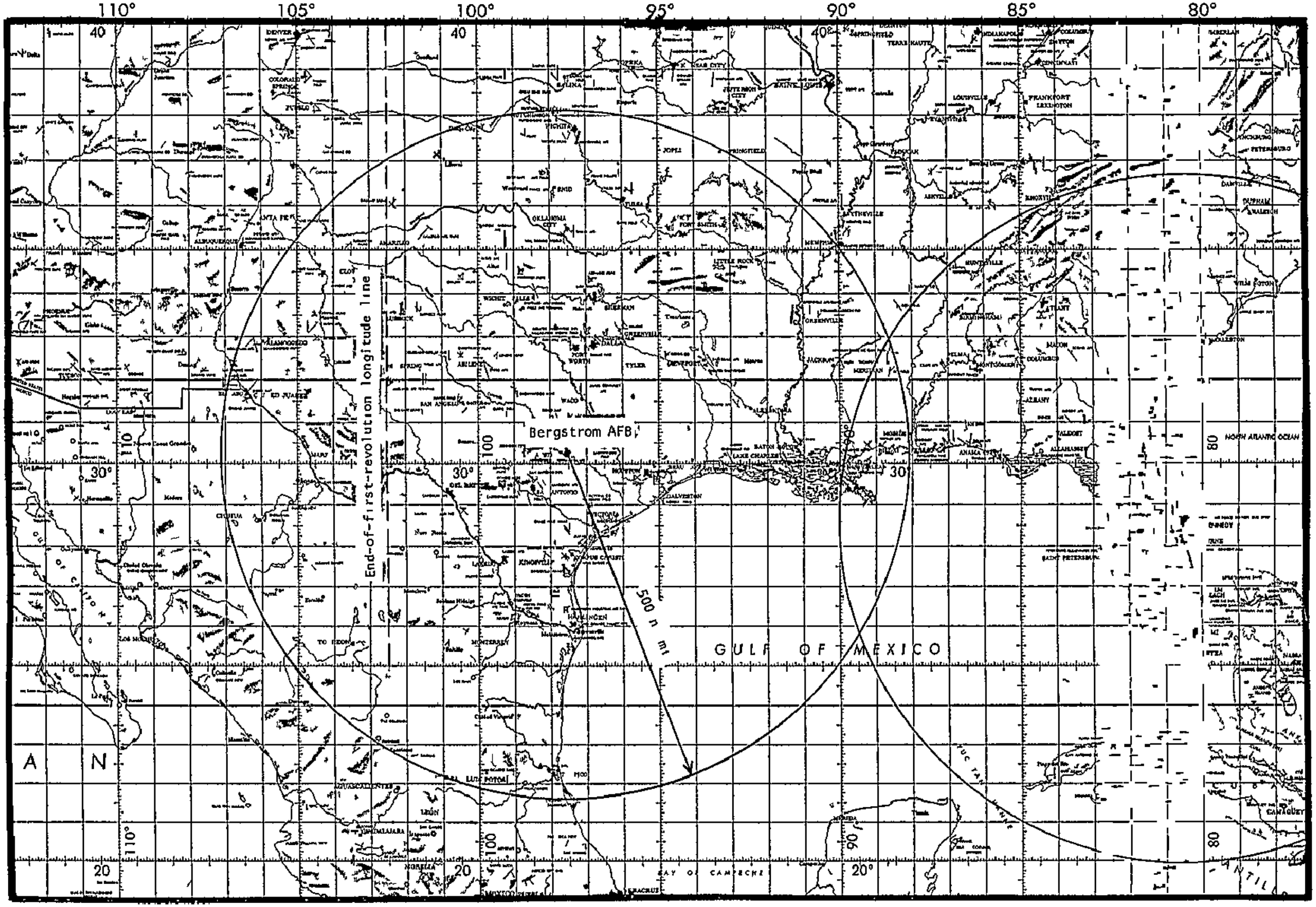


Figure 9- Continental United States airfields to support a 500 n mi crossrange shuttle orbiter

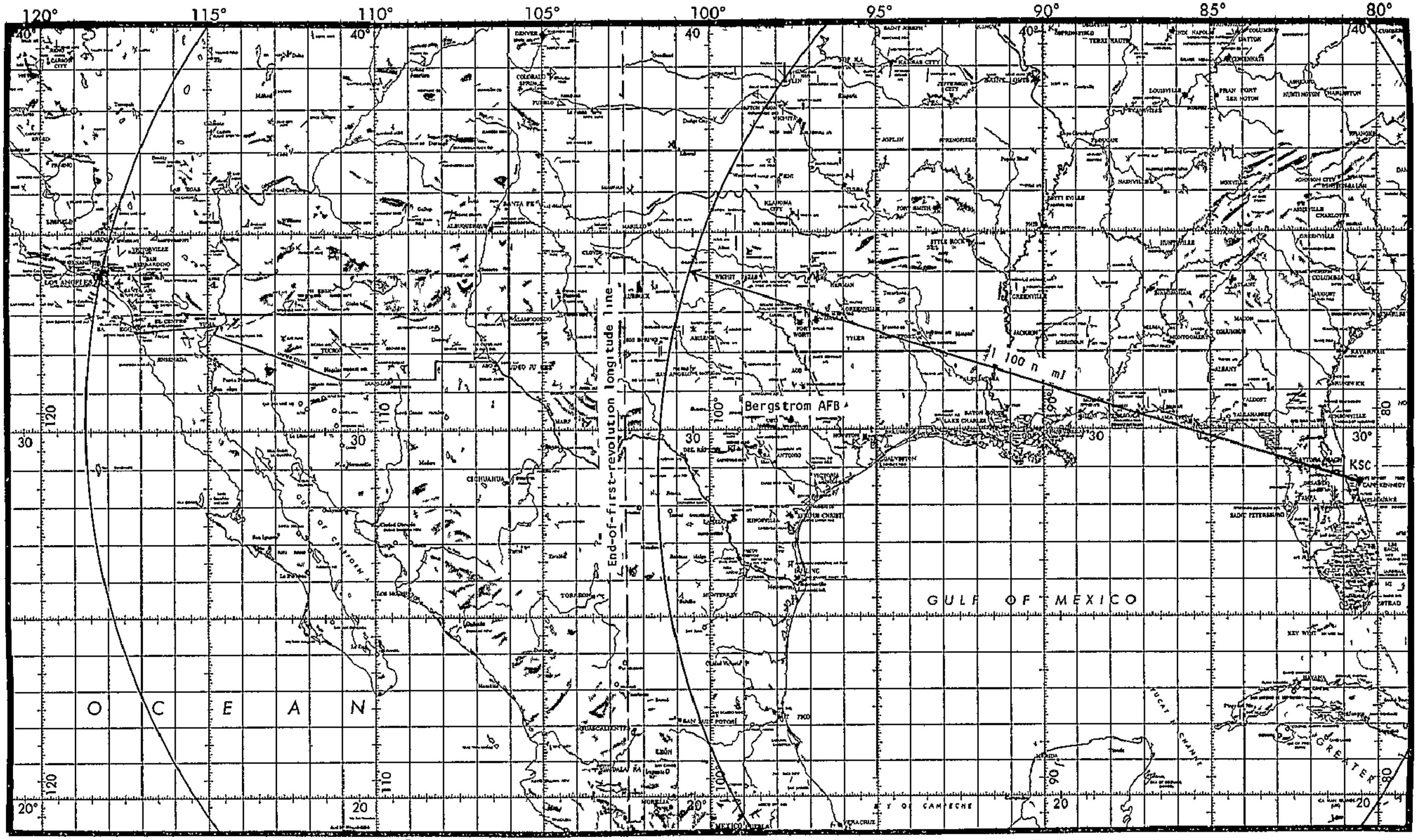


Figure 10 - Continental United States airfields to support a 1 100 n mi crossrange shuttle orbiter

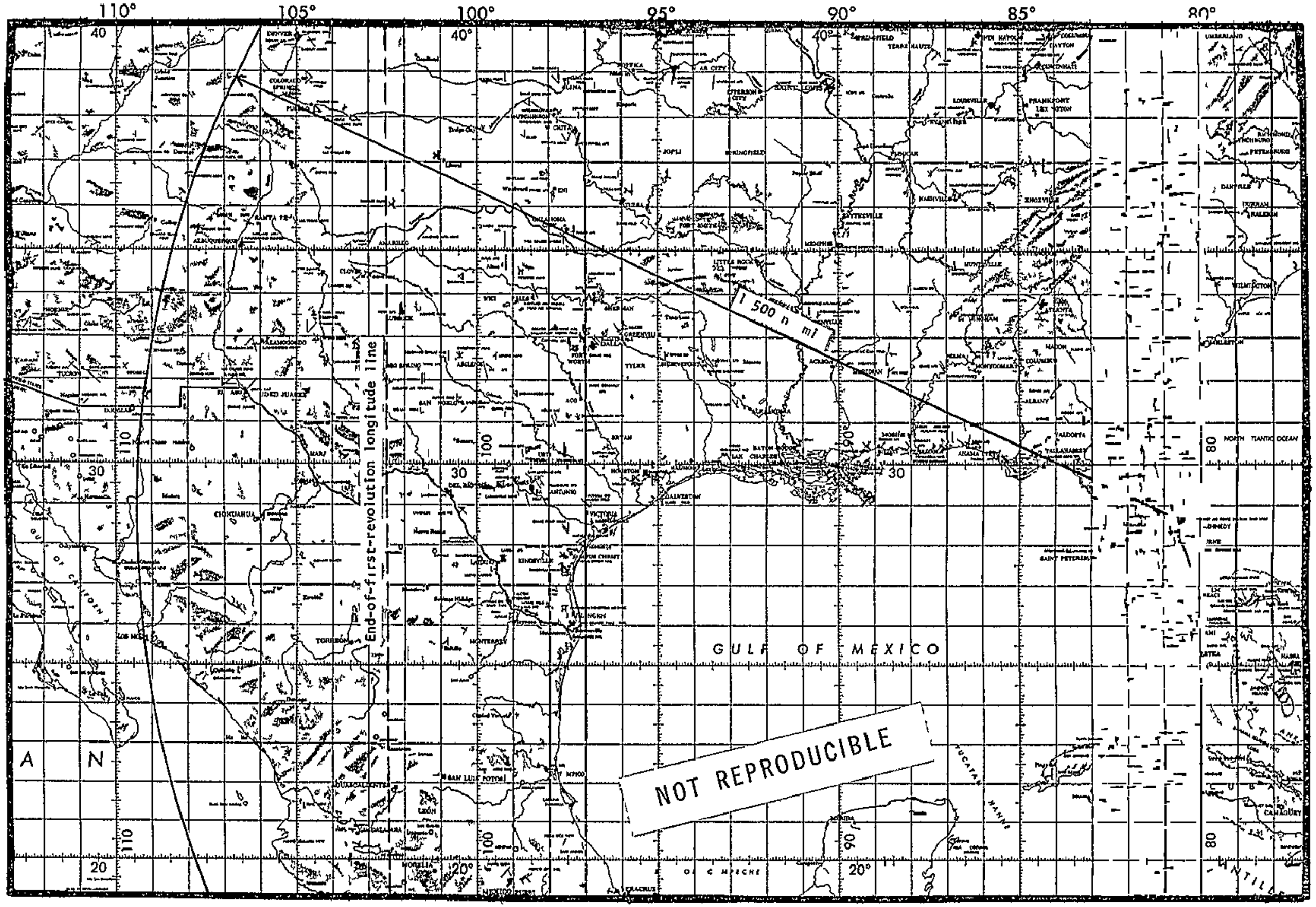


Figure 11 -Continental United States airfields to support a 1,500 n mi crossrange shuttle orbiter

Figure 12 - Landing opportunities at selected airfields

EXPLANATION

The data depicted in this figure were obtained from a computer analysis by the Airfield Accessibility Program (AIRAC) No E021 at the Manned Spacecraft Center, Houston, Texas Three specific missions were analyzed (1) a 90° inclination, 400 n mi circular altitude mission, (2) a 55° inclination, 270 n mi circular altitude mission, and (3) a 28 5° inclination, 100 n mi circular altitude mission Data are given for the seven crossranges considered for each mission In a portion of the figure pertaining to a given crossrange, the "X's" above the double line indicate revolutions in which the orbiter has an opportunity to land at the airfields named at the left Whereas, the "X's" below the double line indicate revolutions in which the orbiter has an opportunity to land at one or more of the several airfields designated in the left-hand column The spaces in which no "X" appears illustrate the revolutions where an in-orbit wait in excess of one revolution occurs The maximum number of revolutions in which in-orbit waits occur are designated in the right-hand column under the heading "MIW" (maximum in-orbit wait) for each combination of airfields designated in the left-hand columns

I. Crossrange = 100 n. mi.

Revolution number in which a landing opportunity occurs

Airfield Number	Airfield Name	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
Inside CONUS Airfields																									
1	Kennedy Space Center	X			X			X			X			X			X				X			X	
2	Moody AFB																								
3	Eglin AFB																								
4	New Orleans NAS																								
5	England AFB																								
6	Ellington AFB	X			X			X			X			X				X			X			X	
7	Bergstrom AFB																								
8	Laughlin AFB	X			X			X			X			X				X			X			X	
Outside CONUS Airfields																									
a	Darwin	X			X			X			X				X			X			X			X	
b	N Djili													X				X			X			X	
c	Hickam AFB																								
d	Nandi Intl												X			X				X			X		
e	Lusaka Intl																								
f	Perth Intl																								
g	La Tontouta			X			X			X			X				X			X			X		
h	Andersen AFB																								
i	Ramey AB																								
j	Kadena AB		XX			XX			XX			X	X		X	X			XX			XX			MIW (revs)
k	San Nicolas Is. OLF																								
Using CONUS Airfields 1, 8		XX			XX			XX			XX			XX			X	X			XX			XX	15
Using Airfields 1, 8, a, e, j		XX	XX	X	XXX	XX	X	XXX	XX	X	XXX	X	XX	XX	XX	X	XX	XX	XX	X	XXX	XX	X	XXX	4

II. Crossrange = 150 n. mi.

Airfield Number	Airfield Name	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
Inside CONUS Airfields																									
1	Kennedy Space Center	XX		X	XX			XXX			XXX			XXX			XX	X		X	XX			XXX	
2	Eglin AFB				X			X			X			X			X				X			X	
3	England AFB																								
4	Bergstrom AFB	X			X			X			X			X				X			X			X	
5	Laughlin AFB	X			XX			XX			XX			XX			X	X			XX			XX	
Outside CONUS Airfields																									
a	Darwin	X			X			X			X				X			X			X			X	
b	N Djili	X			X			X			X			X				X			X			X	
c	Hickam AFB		X			X			X			X			XX			XX			X	X		X	
d	Nandi Intl			XX			X	X		X			X			X				X			X		
e	Lusaka Intl	X	X		X	X		X	X		X	X		X	X			X	X		X	X		X	
f	Perth Intl																								
g	La Tontouta			XX			X	X		X	X		X	X			XX			XX			X	X	
h	Andersen AFB																								
i	Ramey AB			X			X			X			X				X			X					
j	Kadena AB		XXX			XXX			XXX			XX	X		X	XX			XXX			XXX			MIW (revs)
k	San Nicolas Is. OLF																								
Using CONUS Airfields 1, 5		XX		X	XXX			XXX			XXX			XXX			XX	X		X	XX			XXX	14
Using Airfields 1, 5, a, c, d, i, j		XX	XXX	XXX	XXX	XXX	XX	XXXX	XXXX	XX	XXXX	XXX	XXX	XXX	XX	XXX	XXX	XXX	XXX	XXX	XXX	XXXX	X	XXXX	4

(a) 28.5° inclination, 100 n. mi. altitude mission

Figure 12. Landing opportunities at selected airfields

III Crossrange = 200 n mi		Revolution number in which a landing opportunity occurs																						
Inside CONUS Airfields																								
Airfield Number	Airfield Name	1 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
1	Kennedy Space Center	XX		X	XX			XXX			XXX			XXX			XX	X		X	XX			XXX	
2	Eglin AFB	X			XX			XX			XX			XX			X	X			XX			XX	
3	Barksdale AFB																								
4	Laughlin AFB	XX			XX X			XXX			XXX			XX	X		X	XX			XXX			XXX	
Outside CONUS Airfields																									
a	Darwin	X			X			X			X				X			X			X			X	
b	N Dili	X			X			X			X			X				X			X	X		X	
c	Hickam AFB	X	X		X	X		X	X		X	X			X X			X X			X X	X		X	
d	Nandi Intl			X X			X	X		X	X		X	X		X	X			X X			X	X	
e	Lusaka Intl	X	X		X	X		X	X		X	X		X	X			X	X		X	X		X	
f	Perth Intl																								
g	La Tontouta			X X			X	X		X	X		X	X			X X			X X			X	X	
h	Andersen AFB	X														X			X			X			
i	Ramey AB			X			X			X				X			X			X	X		X	X	
j	Kadena AB		X XX			XX X			XXX			XX	X		X	XX			XXX			XXX			MIW
k	San Nicolas Is OLF																								(revs)
Using CONUS Airfields 1, 4		XXX		X	XXXX			XXXX			XXXX			XXX	X		XX	XX		X	XXX			XXXX	13
Using Airfields 1, 4, c, d, i, j		XXX	X XX	X X X	XXXX	XX X	X X	XXXX	XXXX	X X	XXXX	XXX	X X	X XXX	XXX	X X	X XX	XX	XXX	X X X	XXX	XXXX	X X	XXXX	3

IV Crossrange = 250 n mi																								
Inside CONUS Airfields																								
Airfield Number	Airfield Name	1 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
1	Kennedy Space Center	XX		X	X X			XXX			XXX			XXX			XX	X		X	XX			XXX	
2	Biggs AAF	X			X			X			X			X				X			X			X	
3	Bergstrom AFB	X			XX			XX			XX			XX			X	X			XX			XX	
4	Columbus AFB																								
Outside CONUS Airfields																									
a	Darwin	X		X	X		X	X		X	X		X		X		X	X		X	X			X	
b	N Dili	X	X		X	X		X	X		X		X	X	X			X	X		X	X		X	
c	Hickam AFB	X	X		X	X		X	X		X	X			X X			X X			X	X		X	
d	Nandi Intl			X X			X	X		X	X		X	X		X	X			X X			X	X	
e	Lusaka Intl	X	X		X	X		X	X		X	X		X	X			X	X		X	X		X	
f	Perth Intl				X			X			X			X			X				X			X	
g	La Tontouta			X X			X	X		X	X		X	X			X X			X X			X	X	
h	Andersen AFB	X	X		X		X	X		X		X	X		X	X		X	X		X		X		
i	Ramey AB	X		X	X		X	X		X	X			X	X		X	X		X	X		X	X	
j	Kadena AB	X	X XX			XXX X			XXXX			XX	X		XX	X			XXX			XXX			MIW
k	San Nicolas Is OLF																								(revs)
Using CONUS Airfields 1, 2		XX		X	XXX			XXX			XXX			XXX			XX	X		X	XX			XXX	14
Using Airfields 1, 2, a, c, d, h, i, j		XXX	XX XX	XXXXX	XXXX	XXX	XXXXX	XXXXX	XXXX	XXXX	XXXXX	XXX	XX XX	XXXX	XXXX	XXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXXX	XXX	XXXX	2

FOLDOUT FRAME 1

Fig 12 (a) cont

FOLDOUT FRAME 2

Revolution number in which a landing opportunity occurs

V Crossrange = 500 n mi		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	MIW (revs)
Inside CONUS Airfields																									
Airfield Number	Airfield Name																								
1	Kennedy Space Center	XXX		XX	X XX		X	XXX X		X	XXXX			XXXX	X		XXX	X X		XX	XXX		X	XXXX	
2	Bergstrom AFB	XX		X	XX X			XXXX			XXXX			XXX	X		XX	XX		X	XXX			XXXX	
Outside CONUS Airfields																									
a	Darwin	XX		XX	XX		XX	XX		XX	XX		X	X X	X		XX	XX		XX	X		XX	X	
b	N Djili	X	XX		X	XX		X	XX		X	X	X	X X		XX		X	XX		X	XX			
c	Hickam AFB	XX	XXX		XXXX	XX		XXXXX	X		XX	XXXX		X	XXXX			XXXXXX	X		XXXX	XX		XX	
d	Nandi Intl		X	XX	X X		XXX	XX		XXX	X		XXX	XX		XX	XXX		X	XX X			XX	XX	
e	Lusaka Intl	XX	X		XX			XX	X		XX	XX		X	XX		X	XX	XX		XX	XX		XX	
f	Perth Intl	X		X	XX			XXX			XXX			XXX			X XX	XX		X	XX			XXX	
g	La Tontouta			XXXXX			XXXX	X		XXXX	XX		XX	XXXX			XXXXX			XXXXX			XXXX	XX	
h	Andersen AFB	X	XX		XX	X	X	X	X	XX		XX	XX		XX	XX		XX	XX		XX	XX			
i	Ramey AB	XX		XX	XX		XX	XX	X	X	XX			X	X		X	XX		XX	XX		XX	XX	
j	Kadena AB	X	XXXX			XXX XX	X		X XX	X		XXXXX	XX		XX	XXX			XXXX			XXXXX			
k	San Nicolas Is OLF	X XX			XX X			XXX			XX	X		X	XX			XXX			XXX			XX	
Using CONUS Airfields 1, 2		XXX		XXXXX				XXXXX			XXXXX			XXXXX			XXX	XX		XXX	XXX			XXXXX	12
Using Airfields 1, 2, c, g, j		XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	2
Using Airfields 1, 2, b, c, d, g, h, i, j		XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	1

VI Crossrange = ,100 n mi		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	MIW (revs)
Inside CONUS Airfields																									
Airfield Number	Airfield Name																								
1	Kennedy Space Center	XXXX		XXX	X XXX		XX	XXX X		X	XXXXXX			XXXXX	XX		XXXX	XXX		XXX	XXX		XX	XXXX	
2	Bergstrom AFB	XXX		XX	X XX		X	XXXX X			XXXXX			XXXXX	X		XXX	XXX		XX	XXXX		X	XXXX	
Outside CONUS Airfields																									
a	Darwin	XXX		XXXXX	XXXX		XXXX	XXXX		XXXXX	XXXX		XXXX	XXXXX		X	XXXXX	XXX		X XXXX	XXXX		X XXX	XXXXX	
b	N Djili	XX	XXXX		XXX	XXXX		XXX	XXXX		XXX	XXXX	X	X XX	XXXX		XX	XX	XXXX		XX X	XXXX		X X	
c	Hickam AFB	XX	XXXX		XXXXX	XXX		XXXX	XX X		XXX	XXXXX	X	XXXXX	XX		X	XXXXXX	X		XXXX	XXXX		XXX	
d	Nandi Intl	X	X	XX XX	XX		XXXXX	XXX		XXXXX	XX		XXX	XXXXX		XX	XXXXX	XX		XXXXXX	XX		XXXXX	XXX	
e	Lusaka Intl	XXXXX	XX		XXXXXX	X		XXXX	XXXX		XXXXX	XXXX		XXXXX	XXXX		X	XXXXX	XX		X XXXX	XXX		X XXX	
f	Perth Intl	XX		XXXX	XX		XX	XXXX		X	XXXXX			XXXXX			XXXX	XX		XXX	XXX		XX	XXXX	
g	La Tontouta	X	X	XXXXX	X		XXXXX	XX		XXXXX	XX		XXXX	XXXXX		XX	XXXXX		XX	XXXXX	X	X	XXXXX	XXX	
h	Andersen AFB	X	XX X	XXXX	XXX	XX XX	XX	XXXX	XXX	XX	X	XXXXX	XXX		XXXX	XXX		XXXX	XXXX		XXX	XXXXX		X	
i	Ramey AB	XXXX		XXXXX	XXX		XXXX	XXXX		XXX	XXXX	X		XXXXXX	XXX		X XXXX	XXX		XXXXX	XXX		XXXX	XXX	
j	Kadena AB	XX	X XX	X		XXXX	XXX		XX XX	X		XXXXX	X		XXXX	XXX		XX	XXXX			XXXXX	X		
k	San Nicolas Is OLF	X XXX		XXXX	X			XXXXX	X		XXXXX	X		XXXX	X			XXXXX			XXXXX			XXX	
Using CONUS Airfields 1, 2		XXXX		XXXXX	XX			XXXXX	X	X	XXXX			XXXXX	X		XXXX	XXX		XXXXX	XXX		XXXXX	XXX	10
Using Airfields 1, 2, d, h		XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	2
Using Airfields 1, 2, c, d, h		XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	1

Fig 12 (a) cont

FOLDOUT FRAME 1

FOLDOUT FRAME 2

VII. Crossrange = 1,500 n. mi		Revolution number in which a landing opportunity occurs (1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110, 115)	MTW (revs)
Inside CONUS Airfields			
Airfield Number	Airfield Name		
1	Kennedy Space Center		
Outside CONUS Airfields			
a	Darwin		
b	N Djili		
c	Hickam AFB		
d	Nandi Intl		
e	Lusaka Intl		
f	Perth Intl		
g	La Tontouta		
h	Andersen AFB		
i	Ramey AB		
j	Kadena AB		
k	San Nicolas Is OLF		
Using CONUS Airfields 1			10
Using Airfields 1, i, j			2
Using Airfields 1, b, d			1

Figure 12 (a) cont

FOLDOUT FRAME 1

FOLDOUT FRAME 2

I. Crossrange = 100 n. mi.		Revolution number in which a landing opportunity occurs																							
Inside CONUS Airfields																									
Airfield Number	Airfield Name	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
1	Kennedy Space Center			X			X			X			X			X									
2	Moody AFB																								
3.	Eglin AFB																								
4	New Orleans NAS																								
5.	England AFB																								
6	Ellington AFB		X		X			X			X			X			X			X		X			
7.	Bergstrom AFB		X		X			X			X			X			X								
8	Laughlin AFB						X			X			X			X		X			X				
Outside CONUS Airfields																									
a.	Darwin	X																							
b	N Djili																								
c	Hickam AFB	X			X			X		X			X			X	X		X	X					
d.	Nandi Intl	X		X	X	X		X	X	X		X	X		X	X		X	X	X					
e	Lusaka Intl	X																							
f	Perth Intl	X		X	X		X	X		X	X		X		X			X			X				
g	La Tontouta																								
h.	Andersen AFB																								
i	Ramey AB																								MIW (revs)
j	Kadena AB		X			X			X			X		X											
k.	San Nicolas Is. OLF												X			X			X	X	X				
Using CONUS Airfields 1, 6			X	X	X		X	X		X	X		X	X		X	X			X		X			14
Using Airfields 1, 6, d, f, j, k		X X	X X	X X X	X X X	X X	X X	X X X	X X	X X X	X X	X X	X X X X	X X	X X	X X X X	X	X X	X X X	X X	X X X	X			5

II. Crossrange = 150 n. mi.																									
Inside CONUS Airfields																									
Airfield Number	Airfield Name	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
1	Kennedy Space Center			X			X			X			X			X		X			X				
2	Eglin AFB																								
3	England AFB																			X		X			
4.	Bergstrom AFB		X		X			X		X	X		X	X		X	X	X		X	X				
5	Laughlin AFB	X		X			X			X			X			X		X			X				
Outside CONUS Airfields																									
a.	Darwin	X			X			X			X														
b	N Djili		X			X			X																
c	Hickam AFB	X			X	X		X	X	X		X	X	X		X	X		X	X					
d	Nandi Intl	X		X	X	X		X	X	X		X	X		X	X		X	X	X					
e	Lusaka Intl	X			X			X		X			X												
f	Perth Intl	X		X	X		X	X		X	X		X	X	X	X		X	X		X				
g	La Tontouta																								
h	Andersen AFB																								
i	Ramey AB																								
j	Kadena AB																				X				MIW (revs)
k	San Nicolas Is OLF	X			X		X	X		X	X		X	X		X	X		X	X	X				
Using CONUS Airfields 1, 4, 5		X	X	X	X	X	X	X		X	X		X	X		X	X	X		X	X				9
Using Airfields 1, 4, 5, b, c, d, f		X X X	X X	X X	X X X	X X X	X X	X X X	X X X	X X X	X X	X X	X X X	X X X	X X	X X X	X X	X X X	X X X	X X X	X X				4

(b) 55° inclination, 270 n. mi. altitude mission

Fig. 12 (cont.)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

III. Crossrange = 200 n. mi.		Revolution number in which a landing opportunity occurs																						
Inside CONUS Airfields																								
Airfield Number	Airfield Name	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115
1	Kennedy Space Center			X			X			X			X			X		X			X			
2.	Eglin AFB																							
3	Barksdale AFB							X			X		X	X		X	X	X	X		X			
4	Laughlin AFB	X		X			X			X			X			X		X			X			
Outside CONUS Airfields																								
a.	Darwin	X			X			X			X			X		X			X					
b.	N Djili		X			X			X			X			X									
c.	Hickam AFB	X	X		X	X		X	X	X		X	X	X		X	X		X	X				
d	Nandi Intl	X		X	X	X		X	X	X		X	X		X	X		X	X	X				
e	Lusaka Intl	X			X			X		X			X			X			X					
f	Perth Intl	X		X	X		X	X		X	X		X	X	X	X		X	X		X			
g	La Tontouta																							
h	Andersen AFB																							
i	Ramey AB		X	X	X		X	X																
j	Kadena AB								X			X			X			X			X			
k	San Nicolas Is. OLF	X	X		X	X	X	X		X	X		X	X		X	X		X	X	X			

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	MIW (revs)
Using CONUS Airfields 1, 3, 4	X		X			X	X		X	X	X	X	X		X	X	X X	X		X				14
Using Airfields 1, 3, 4, c, d, f, i, j, k	XXX X	XXX	X XX	XX XX	X X X	XXX	XXX	X XX	XXXXX	XXX	X XX	XXXX	XXXX	X XX	XXXX	XX X	XX XX	XX XX	X X	X XXX				3

IV. Crossrange = 350 n. mi.																								
Inside CONUS Airfields																								
Airfield Number	Airfield Name	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115
1	Kennedy Space Center			X			X			X			X			X		X			X			
2	Biggs AAF	X		X																				
3.	Bergstrom AFB	X	X	X	X		X	X		X	X		X	X		X	X	X	X		X			
4.	Columbus AFB																							
Outside CONUS Airfields																								
a	Darwin	X			X			X			X			X		X		X	X		X			
b	N Djili		X			X			X			X			X		X			X				
c	Hickam AFB	X	X		X	X		X	X	X		X	X	X		X	X		X	X				
d	Nandi Intl	X		X	X	X		X	X	X		X	X		X	X		X	X	X				
e	Lusaka Intl	X			X			X		X			X			X			X					
f.	Perth Intl	X		X	X		X	X		X	X		X	X	X	X		X	X		X			
g	La Tontouta																							
h	Andersen AFB	X			X			X			X													
i	Ramey AB		X	X	X		X	X		X	X		X	X	X		X	X	X					
j	Kadena AB		X	X		X	X		X	X		X	X	X	X		X	X		X	X			
k	San Nicolas Is. OLF	X	X		X	X	X	X		X	X		X	X		X	X		X	X	X			

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	MIW (revs)
Using CONUS Airfields 1, 3	X	X	X	X		X	X		X	X		X	X		X	X	X	X		X				9
Using Airfields 1, 2, 3, c, d, f, i, k	XXX	XX X	XXX	XXX	X XX	XXXX	XXX	X XX	XXXX	XXX	X XX	XXXX	XXX X	XXX	XXX	XX X	XX XX	XX XX	X XX	XXX				2

Fig. 12 (b) cont.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

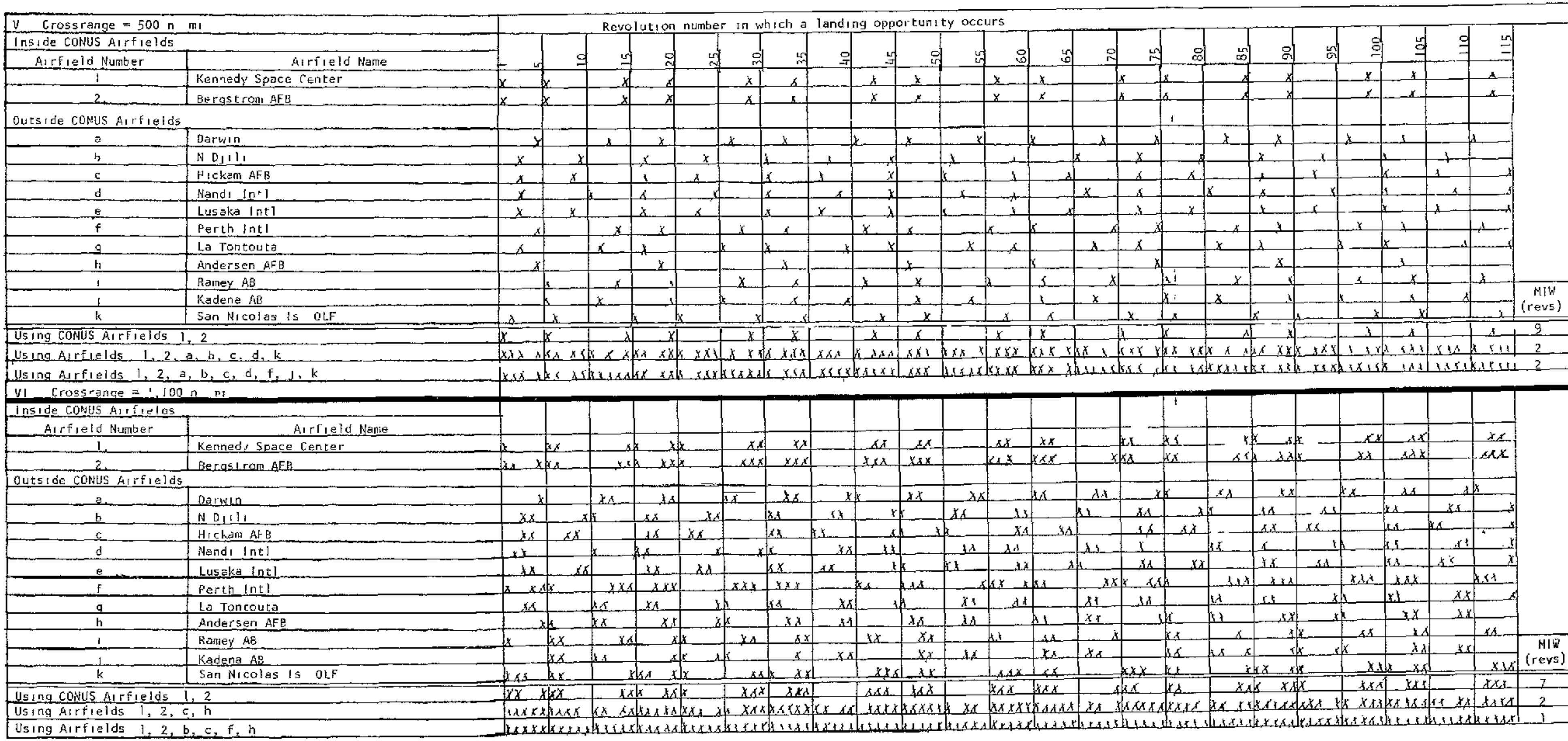


Figure 12 (b) cont

VII. Crossrange = 1,500 n. mi.		Revolution number in which a landing opportunity occurs																							
Airfield Number	Airfield Name	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	MIW (revs)
Inside CONUS Airfields																									
1.	Kennedy Space Center																								
Outside CONUS Airfields																									
a	Darwin																								
b	N Djili																								
c	Hickam AFB																								
d	Nandi Intl																								
e	Lusaka Intl																								
f	Perth Intl																								
g	La Tontouta																								
h	Andersen AFB																								
i	Pemey AB																								
j	Kadena AB																								
k	San Nicolas is. OLF																								
Using CONUS Airfields 1																									7
Using Airfields 1, j																									3
Using Airfields 1, c, j																									1

Figure 12 (b) cont

FOLDOUT FRAME 1

FOLDOUT FRAME 2

I. Crossrange = 100 n mi

Revolution number in which a landing opportunity occurs

Airfield Number	Airfield Name	1–5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	MIW (revs)
Inside CONUS Airfields																									
1	Kennedy Space Center	X																							
2	Moody AFB		X				X																		
3	Eglin AFB								X				X												
4	New Orleans NAS														X				X						
5	England AFB																			X					
6	Ellington AFB				X																				
7	Bergstrom AFB					X				X															
8	Laughlin AFB	X										X				X									
Outside CONUS Airfields																									
a	Darwin							X					X												
b	N Djili	X										X													
c	Hickam AFB			X				X																	
d	Nandi Intl													X				X							
e	Lusaka Intl														X				X						
f	Perth Intl										X					X	X								
g	La Tontouta										X				X										
h	Andersen AFB															X									
i	Ramey AB			X																X					
j	Kadena AB			X					X																
k	San Nicolas Is. OLF				X																				
Using CONUS Airfields 1, 2, 3, 4, 5, 6, 7, 8		X	X		X	X	X		X	X		X	X		X	X			X	X					14
Using Airfields 1, 2, 3, 4, 5, 6, 7, 8 a, b, c, d, f, g, i		X X	X	X X	X	X	X	X X	X	X	X X	X X	X X	X	X X X	X X	X	X	X X	X X					7

II. Crossrange = 150 n mi

Airfield Number	Airfield Name	1–5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	MIW (revs)
Inside CONUS Airfields																									
1	Kennedy Space Center	X															X					X			
2	Eglin AFB						X		X				X												
3	England AFB				X														X	X					
4	Bergstrom AFB					X				X		X				X									
5	Laughlin AFB	X										X				X									
Outside CONUS Airfields																									
a	Darwin		X					X					X						X						
b	N Djili	X										X													
c	Hickam AFB			X				X																	
d	Nandi Intl							X						X				X							
e	Lusaka Intl								X						X				X						
f	Perth Intl										X					X	X					X			
g	La Tontouta										X				X						X				
h	Andersen AFB															X				X					
i	Ramey AB			X										X						X					
j	Kadena AB		X	X					X																
k	San Nicolas Is OLF				X	X															X				
Using CONUS Airfields 1, 2, 3, 4, 5		X			X	X	X		X	X		X	X			X	X		X	X		X			15
Using Airfields 1, 2, 3, 4, 5, a, c, e, f, i, j, k		X	X X	X X	X X	X X	X	X X	X X X	X	X	X	X X	X	X	X X	X X		X X X	X X	X	X X			6

(c) 90° inclination, 400 n mi altitude mission

Fig 12 (cont)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

III. Crossrange = 200 n. mi.		Revolution number in which a landing opportunity occurs																							
Inside CONUS Airfields																									
Airfield Number	Airfield Name	1 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
1	Kennedy Space Center	X	X				X										X					X			
2.	Eglin AFB		X				X		X				X		X				X						
3	Barksdale AFB				X	X													X	X					
4	Laughlin AFB	X				X				X		X				X		X							
Outside CONUS Airfields																									
a	Darwin		X					X					X						X						
b.	N Dili	X				X						X						X							
c.	Hickam AFB	X		X				X						X											
d	Nandi Intl							X						X											
e	Lusaka Intl								X						X				X						
f	Perth Intl																								
g	La Tontouta				X						X				X		X				X				
h	Andersen AFB				X					X						X				X	X				
i	Ramey AB			X										X					X	X					
j	Kadena AB		X	X					X					X											MIW (revs)
k	San Nicolas Is. OLF				X	X					X										X				
Using CONUS Airfields 1, 2, 3, 4		XX	X		X	X	X		X	X		X	X		X	X	X	X	X	X		X			8
Using Airfields 1, 2, 3, 4, a, b, c, g, h, i		XXXX	XXX	XX	XXX	XX	X	XX	XX	XX	X	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	X			5

IV. Crossrange 250 n. mi.																									
Inside CONUS Airfields																									
Airfield Number	Airfield Name	1 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
1	Kennedy Space Center	X	X				X										X					X			
2	Biggs AAF	X	X					X	X									X							
3.	Bergstrom AFB				X	X				X		X				X									
4.	Columbus AFB		X				X		X				X		X				X	X					
Outside CONUS Airfields																									
a	Darwin		X				X	X					X	X					X						
b	N Dili	X				X						X					X	X							
c	Hickam AFB	X		X				X	X					X				X							
d	Nandi Intl			X				X				X		X				X		X					
e	Lusaka Intl				X				X					X	X				X		X				
f.	Perth Intl					X				X	X					X	X					X			
g	La Tontouta				X					X	X				X		X				X				
h	Andersen AFB				X					X						X				X	X				
i	Ramey AB			X										X					X	X					
j	Kadena AB		X	X					X	X				X					X						MIW (revs)
k	San Nicolas Is. OLF				X	X					X								X		X				
Using CONUS Airfields 1, 2, 3, 4		XX	XX		X	X	X	X	XX	X		X	X		X	X	X	X	X	X		X			8
Using Airfields 1, 2, 3, 4, a, b, c, d, e, f, g, h, i, j, k		XXXX	XXXX	XXX	XXXXX	XXX	XX	XXX	XXXXX	XXXX	XXX	XXX	XX	XXXX	XXX	XXX	XXXX	XXX	XXXX	XXX	XXXX	XX			3

Fig. 12 (c) cont.

FOLDOUT FRAME

FOLDOUT FRAME 2

V Crossrange = 500 n mi		
Inside CONUS Airfields		
Airfield Number	Airfield Name	MIW (revs)
1	Kennedy Space Center	
2	Bergstrom AFB	
Outside CONUS Airfields		
a	Darwin	
b	N Djili	
c	Hickam AFB	
d	Nandi Intl	
e	Lusaka Intl	
f	Perth Intl	
g	La Tontouta	
h	Andersen AFB	
i	Ramey AB	
j	Kadena AB	
k	San Nicolas Is OLF	8
Using CONUS Airfields 1, 2		2
Using Airfields 1, 2, a, b, d, e, f, g		2
Using Airfields 1, 2, a, b, c, d, e, f, g, h, i, k		

VI Crossrange = 1,100 n mi		
Inside CONUS Airfields		
Airfield Number	Airfield Name	MIW (revs)
1	Kennedy Space Center	
2	Bergstrom AFB	
Outside CONUS Airfields		
a	Darwin	
b	N Djili	
c	Hickam AFB	
d	Nandi Intl	
e	Lusaka Intl	
f	Perth Intl	
g	La Tontouta	
h	Andersen AFB	
i	Ramey AB	
j	Kadena AB	
k	San Nicolas Is OLF	7
Using CONUS Airfields 1, 2		2
Using Airfields 1, 2, c, e, h		1
Using Airfields 1, 2, c, e, f, g, h, k		

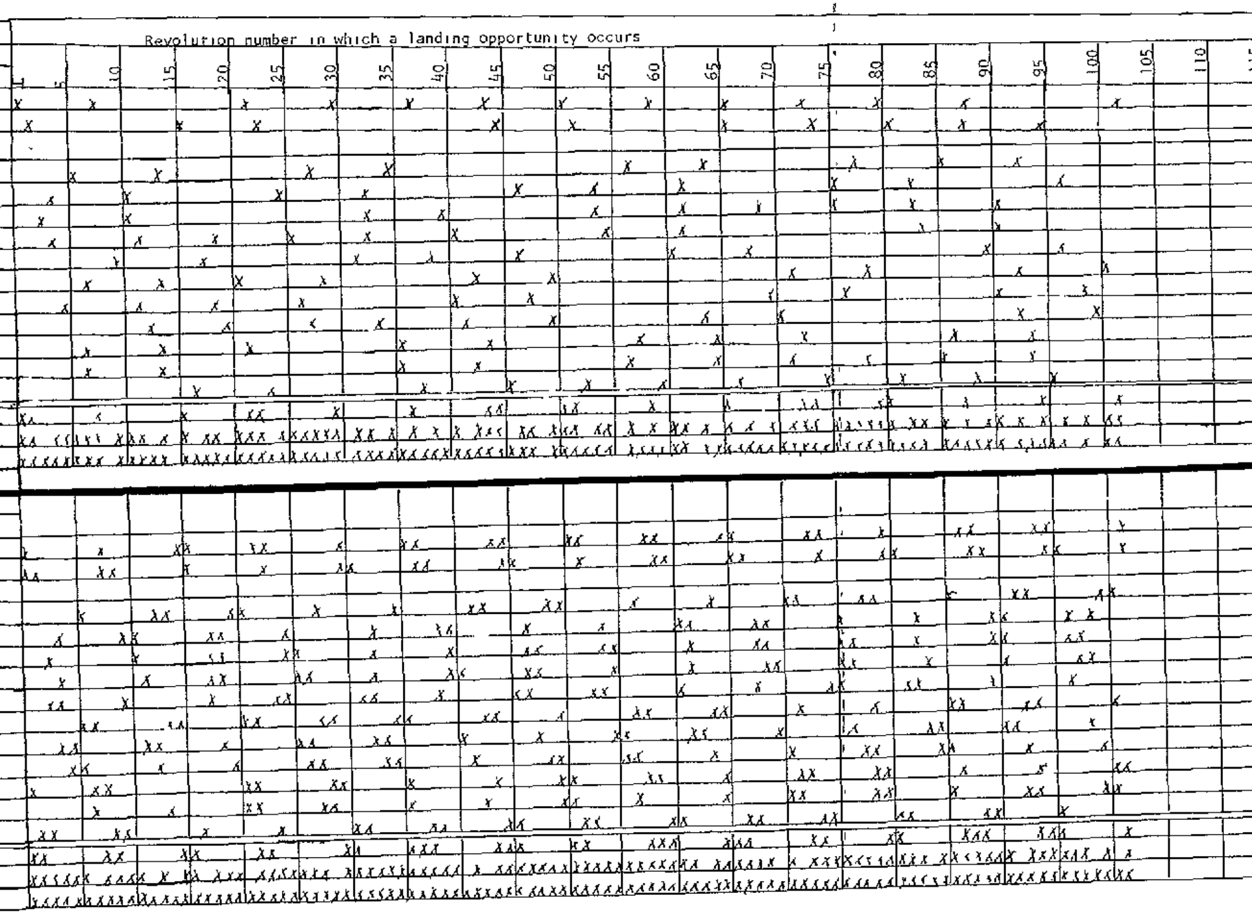


Fig 12 (c) cont

FOLDOUT FRAME 2

FOLDOUT FRAME 1

VII. Crossrange = 1,500 n. mi.		Revolution number in which a landing opportunity occurs																							
Inside CONUS Airfields																									
Airfield Number	Airfield Name	1–5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
1	Kennedy Space Center	XX	XXX	X	X	XX	XX	X	XX	XX		XX	XX	X	X	XX	XX	X	XX	XX	X	X			
Outside CONUS Airfields																									
a	Darwin		XX	XX	X	X	X	XX		XX	XX		XX	XX		XX	XX	X	X	XX	X	X			
b	N Djili	X	X	X	XX	X	X	XX	XX		XX	XXX		XX	XX		XX	XX	XX		XX				
c	Hickam AFB	XX	X	X	XX	X	X	XX	XX		XX	XX		XX	XX		XX	XX	XX		XX				
d	Nandi Intl	XX		XX	XX		XX	XX	X	X	XX	X	X	XXX	XX		XX	XXX	XX		XX				
e	Lusaka Intl	XX	X	X	XX	XX		XX	XX		XX	XX		XX	XX	X	X	XX	XX		XX				
f	Perth Intl	X	XX	XX	X	XX	XX	X	X	XXX	XX	X	XX	XX		XXX	XXX		XX	XX	X	X			
g	La Tontouta	XX		XX	XX		XX	XX		XX	XXX	X	X	XX	XX	X	XX	XX		XX	XX				
h	Andersen AFB	X	X	XX	XX		XX	XX		XX	XX		XX	XX	X	XX	XX	X	X	XX	XX				
i	Ramey AB	X	XX	X	X	X	XX		XX	XX	X	X	XX	X	X	XX	XX		XX	XXX		XX			
j	Kadena AB		XXX	XXX		XX	XX	X	XX	XX	X	X	X	XX		XX	XX		X	XX	X	X			
k	San Nicolas Is. OLF	XX	XX		XX	XXX		XX	XX	XX	X	XXX	X	X	XX	XX		XX	XXX	X	XX				MIW (revs)
Using CONUS Airfields 1		XX	XXX	X	X	XX	XX	X	XX	XX		XX	XX	X	X	XX	XX	X	XX	XX		XX			7
Using Airfields 1, d, e, h		XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XX			2
Using Airfields 1, a, d, e, h, k		XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	XX			1

Fig. 12 (c) concluded

FOLDOUT FRAME 1

FOLDOUT FRAME 2

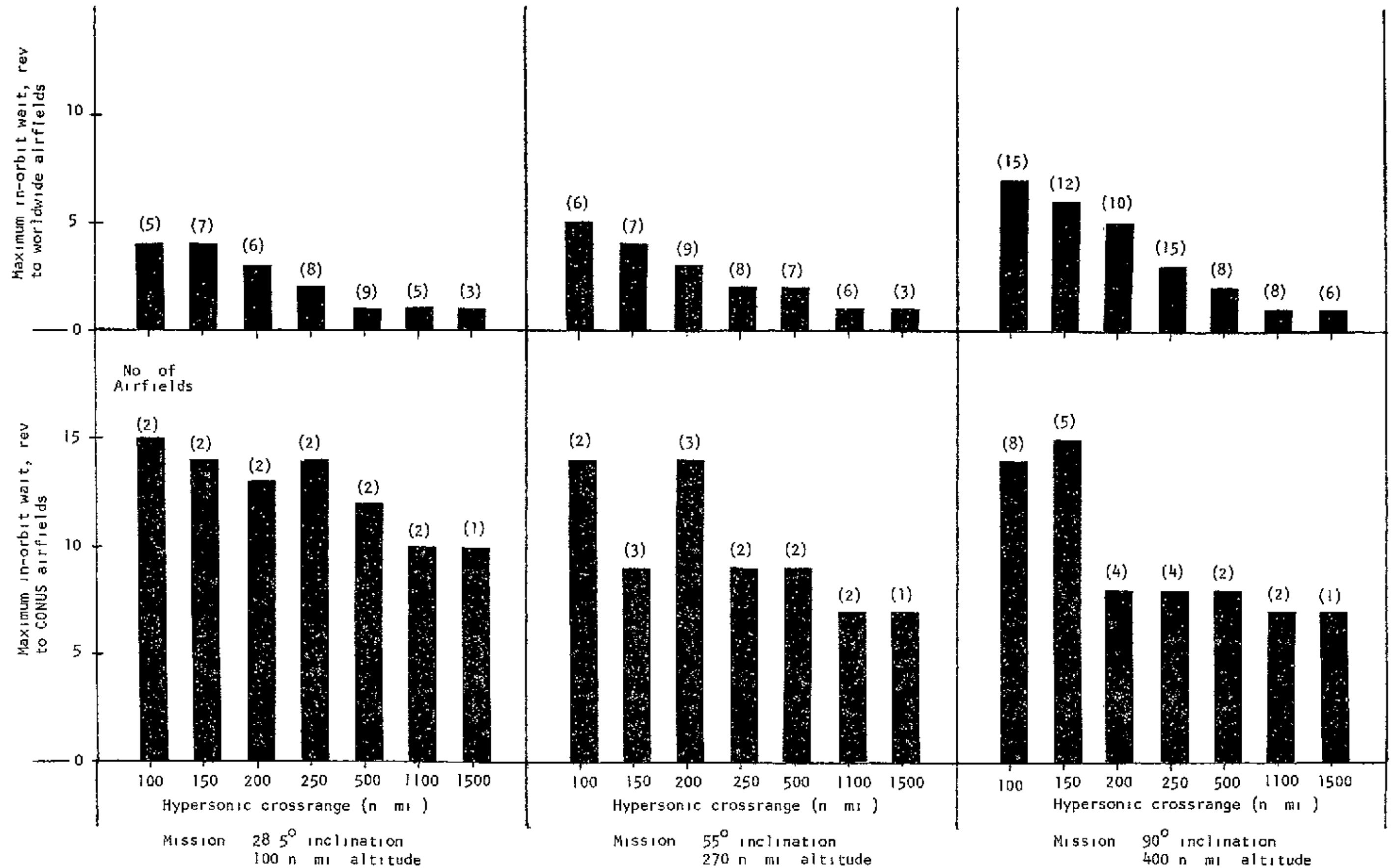


Figure 13 - Crossrange effects upon in-orbit waits

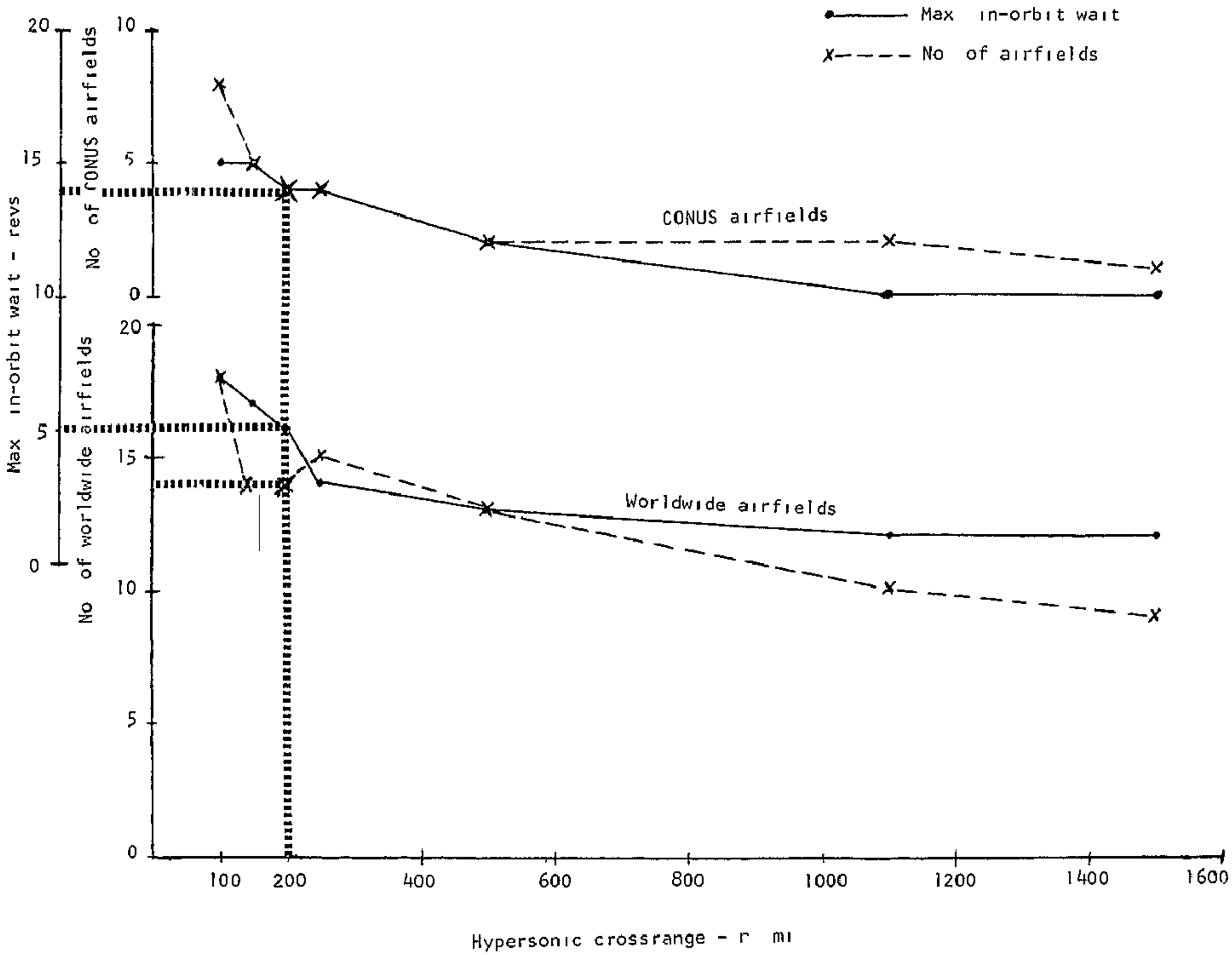


Figure 14 - Optimized crossrange, maximum in-orbit wait, and number of airfields

APPENDIX--AIRFIELD DESCRIPTIONS

Explanation of Terms

Several terms used in this appendix need explaining Under the subheadings "Runway" and "Taxiway," the surface strength is designated by three methods One is by listing the heaviest known aircraft to land at the field without causing runway or taxiway surface damage A second method is by listing the single-wheel loading (SWL) in pounds which the surface will withstand The listed SWL includes information submitted in terms of equivalent single-wheel loading and single isolated wheel loading The third method is by listing the maximum pressure the runway will support in psi

Under the subheading "Navigational Aids," several abbreviations are used These abbreviations are defined as follows

ILS--Instrument landing system

GCA--Ground controlled approach

PAR--Precision approach radar

ASR--Approach surveillance radar

UHF--Ultra high frequency

VHF--Very high frequency

VOR--VHF omni directional range

TACAN--Tactical air navigation UHF pulse-type omni range and distance measuring equipment

DME--Distance measuring equipment

VORTAC--Combination VOR and TACAN

RBN--Radio beacon

DF or D/F--Direction finding equipment

Under the subheading "Landing Weather," the abbreviation IFR is for instrument flight rules and means that the landing takes place using the instrumented landing techniques available at the airfield

Each airfield has different low ceilings and low visibilities below which an IFR landing cannot be made (this also excludes the possibility of a visual landing) In this appendix, the ceiling and visibility minimums for each airfield were obtained from appendix reference 1 The percent frequencies of occurrence of these weather minimums for each month for each airfield were obtained from appendix reference 2 The information listed under the subheading "Terrain" was obtained from map studies by the authors, unless otherwise referenced The information by all the other subheadings was obtained from appendix reference 3, unless otherwise designated

Assumed Kennedy Space Center Airfield, Florida (to be built)

Coordinates Approximately 28-28N, 80-34W

Elevation Approximately 9 ft

Runway Length--approximately 10,000 ft, surface--concrete, strength--approximately 250 psi

Taxiways Width--unknown, surface--concrete, strength--approximately 250 psi

Navigational Aids ILS

Controlling Agency National Aeronautics and Space Administration

Weather Forecasting Station at KSC with 24-hour service

Climate This area is subtropical with short, mild winters and hot, humid summers It is often threatened by hurricanes from June through December, but no direct hits are on record The average yearly cloud cover is 0/10 to 3/10 about 40 6 percent of the time, 4/10 to 7/10 about 23 2 percent of the time, and 8/10 to 10/10 about 36 2 percent of the time (reference 4)

Local Features Located on the Atlantic Ocean side of the Florida peninsula on flat and marshy land Elevations range from sea level to 12 feet or so The area is covered with coarse grasses, shrub, palmetto, several citrus groves, and pine trees (reference 4)

Columbus AFB, Mississippi

Coordinates 33-38-35N, 88-26-33W

Elevation 214 ft

Runway Length x width--12,000 ft x 300 ft, extendable, surface--concrete, strength--B-52 support capability

Taxiways Width--175 ft, surface--concrete, strength--B-52 support capability

Navigational Aids ILS, GCA, Approach Control, VORTAC, and D/F

Lighting Approach, threshold, runway, taxiway, flood, obstruction, and rotating beacon

Communications Telephone, telegraph, and teletype

Controlling Agency United States Air Force - Strategic Air Command

Maintenance Facilities Full base maintenance and repair services

Special Purpose Equipment Crash, fire, and cargo handling equipment

Logistics Roads and railroads are available

Medical Facilities Available

Weather Forecasting Station available

Landing Weather The airfield IFR landing weather minimum is for a 200-foot cloud ceiling and a 1/2-mile visibility At worst, this weather occurs 3 percent of the time in January and 4 percent of the time in December All other months have less than a 3-percent frequnency of occurrence at the minimum

Local Features The airfield is located 7 n mi north/northwest of Columbus, Mississippi, in relatively flat terrain The Meridian Intensive Student Jet Training Area is located 20 n mi away and covers an area from west/southwest to southeast of the airfield Vertical obstructions include a 500-foot high structure located 6 n mi south/southeast, a 381-foot high structure located 9 n mi south/southeast, and a 360-foot high structure located 11 n mi west/southwest

Bergstrom AFB, Texas

Coordinates 30-11-42N, 97-39-30W

Elevation 541 ft

Runway Length x width--12,250 ft x 300 ft, estimated extendable, surface--concrete, strength--B-52 support capability, SWL = 77,000 lb, 100 psi

Taxiways Width--175 ft, surface--concrete, strength--B-52 support capability, SWL = 77,000 lb, 100 psi

Navigational Aids ILS, GCA, RBN, Approach Control, VORTAC, TACAN, and D/F

Lighting Approach, threshold, runway, taxiway, obstruction, and rotating beacon

Communications Telephone, teletype, and C/W

Controlling Agency. United States Air Force - Tactical Air Command

Maintenance Facilities Full base maintenance and repair services

Special Purpose Equipment Crash, fire, and cargo handling equipment available

Logistics Roads and railroads available

Medical Facilities Available at field

Weather Forecasting Station on base

Landing Weather The airfield IFR landing weather minimum is for a 200-foot ceiling and a 1/2-mile visibility At worst, during each of the months of January, February, and December, the minimum occurs at most 5 percent of the time

Local Features Located 3 n mi south/southwest of Austin, Texas, near the edge of the Edwards Plateau in an area of rolling hills The Edwards Plateau, 5 to 10 miles to the west, is generally 500 to 600 feet higher than the airfield Vertical obstructions include the Edwards Plateau at 5 to 10 miles west, a 400-foot high structure at 3 n mi northeast, a 1,197-foot high structure at 8 n mi northwest, a 425-foot high structure at 6 n mi west, and a 310-foot high structure at 5 n mi north, near the flight approach path

Biggs AAF, Texas (Fort Bliss AAF)

Coordinates 31-50-52N, 106-22-45W

Elevation 3,947 ft

Runway Length x width--13,572 ft x 300 ft, extendable by 9,999 ft, surface--concrete, strength--B-52 support capability, 285 psi

Taxiways Widths--160 ft and 200 ft, surface--concrete and asphalt, strength--B-52 support capability, 285 psi

Navigational Aids VOR and approach control ILS will have to be installed

Lighting Approach, threshold, runway, taxiway, flood, obstruction, and rotating beacon

Communication Telephone and teletype

Controlling Agency U. S Army

Maintenance Facilities Available

Special Purpose Equipment Crash, fire, and cargo handling equipment available

Logistics Roads and railroads available and in good condition

Medical Facilities Availabe in El Paso

Weather Forecasting Weather station at El Paso Intl , with 24-hour forecasting

Landing Weather The airfield IFR landing weather minimum is for a 400-foot ceiling and a 1 0 n mi visibility At worst, during each of the winter and spring months, the minimum occurs 1 to 3 percent of the time

Local Features Located in relatively flat terrain, approximately 2 n mi northeast of El Paso Vertical obstructions include a mountain range of about 7,000 feet in elevation, located about 4 n mi west, a 5,990-foot elevation peak located 10 n mi southwest, a 5,026-foot peak located 15 n mi northeast, a 6,000-foot mountain range located 20 n mi east, and an 825-foot high structure on the approach path located 5 n mi southwest

Moody AFB, Georgia

Coordinates 30-58-00N, 83-11-35W

Elevation 233 ft

Runway Length x width--8,000 ft x 150 ft, extendable, surface--asphalt, strength--C-135 support capability, 155 psi

Taxiways Width--70 ft, surface--asphalt, strength--C-135 support capability, 155 psi

Navigational Aids ILS, GCA, DF, TACAN, VOR, and Approach Control

Lighting Approach, threshold, runway, taxiway, obstruction, and rotating beacon

Communications Telephone, telegraph, teletype, and C/W

Controlling Agency United States Air Force

Maintenance Facilities Field maintenance, organizational maintenance, and ordinance storage facilities are available

Special Purpose Equipment Crash, fire, and cargo handling equipment available

Logistics Roads and railroads are available

Medical Facilities Available

Weather Forecasting Weather station on base

Landing Weather The airfield IFR landing weather minimum is for a 200-foot ceiling and a 1/2-mile visibility At worst, during November, this weather minimum occurs 5 5 percent of the time and in January, 5 2 percent of the time

Local Features Located in the swamps of Georgia, which are by nature very flat It is 9 miles north/northeast of Valdosta Vertical obstructions include a major power line 3 miles southeast, a 325-foot high structure located 10 miles southwest, a 318-foot high structure located 10 miles southwest, and a 214-foot high structure 8 miles south/southwest

<u>Eglin AFB, Florida</u>

Coordinates 30-29-22N, 86-31-38W

Elevation 85 ft

Runway Length x width--12,000 ft x 300 ft, extendable, surface--asphalt, strength--B-52 support capability, 285 psi

Taxiways Width--175 ft, surface--asphalt, strength--B-52 support capability, 285 psi

Navigational Aids ILS, GCA, RBN, TACAN, VOR, and Approach Control

Lighting Approach, threshold, runway, taxiway, flood, obstruction, rotating beacon, and boundary

Communications Telephone, telegraph, teletype, and C/W

Controlling Agency United States Air Force - Strategic Air Command

Maintenance Facilities Field maintenance, organizational maintenance, and ordinance storage facilities are available

Special Purpose Equipment Crash, fire, and cargo handling equipment are available

Logistics Good roads, railroads, and a navigable waterway are available

Medical Facilities Medical services are available at the base

Weather Forecasting Weather station available on base

Landing Weather The airfield IFR landing minimum is for a 300-foot ceiling and a 3/4-mile visibility At worst, during January, this weather minimum occurs 8 9 percent of the time and during February, 7 5 percent of the time

Local Features Located on the flat Gulf Coast on the west side of Valparaiso, Florida Vertical obstructions include a 300-foot tower located 6 miles east, a 490-foot tower located 9 miles north/northwest, a 251-foot tower located 9 miles northwest, a 352-foot tower located 6 miles west/southwest, and a 200-foot tower located 7 miles southeast of the airfield

New Orleans NAS, Louisiana

Coordinates 29-50-00N, 90-01-00W

Elevation 3 ft

Runway Length x width--8,000 ft x 200 ft, extendable by 4,100 ft, surface--asphalt, strength--C-124 support capability, SWL = 59,000 lb, 79 psi

Taxiways Width--75 ft, surface--asphalt, strength--C-124 support capability, SWL = 59,000 lb, 79 psi

Navigational Aids GCA, DF, RBN, TACAN, and Approach Control

Lighting Approach, threshold, runway, taxiway, obstruction, and rotating beacon

Communications Telephone, telegraph, teletype, and C/W

Controlling Agency United States Navy

Maintenance Facilities Field and organizational maintenance are available

Special Purpose Equipment Crash and fire handling equipment are available

Logistics Good roads, railroads, and a navigable waterway are available

Medical Facilities Medical services are available to the base

Weather Forecasting Weather station on base

Landing Weather The airfield IFR landing weather minimum is for a 100-foot ceiling and a 1/4-mile visibility At worst, in January, this minimum occurs 8 2 percent of the time and in December, 6 2 percent of the time

Local Features Located on the flat Gulf Coast plane 3 miles south of the New Orleans city limits Vertical obstructions include a 410-foot high structure located 10 miles east/northeast, a 305-foot high structure located 5 miles northeast, a 1,046-foot high structure 9 miles northeast, a 237-foot high structure 4 miles northeast, a 357-foot high structure 11 miles north/northeast, a 403-foot high structure 12 miles north/northeast, a 1,049-foot high structure 4 miles

north, a 504-foot high structure 7 miles north/northeast, a 338-foot high structure 5 miles northwest, a 501-foot high structure 8 miles northwest, a 463-foot high structure 10 miles northwest, a 447-foot high structure 12 miles northwest, a 449-foot high structure 5 miles west, and a 242-foot high structure located 8 miles southwest of the airfield

England AFB, Louisiana

Coordinates 31-19-25N, 92-32-43W

Elevation 89 ft

Runway Length x width--9,350 ft x 150 ft, extendable by 9,999 ft, surface--concrete, strength--C-141 support capability, 180 psi

Taxiways Width--75 ft, surface--concrete, strength--C-141 support capability, 180 psi

Navigational Aids GCA, DF, RBN, VORTAC, TACAN, and Approach Control.

Lighting Approach, threshold, runway, taxiway, obstruction, and rotating beacon

Communications Telephone, telegraph, teletype, cable, and C/W

Controlling Agency United States Air Force - Tactical Air Command

Maintenance Facilities Organizational maintenance and ordinance storage facilities are available

Special Purpose Equipment Crash, fire, and cargo handling equipment are available

Logistics Good roads and railroads are available

Medical Facilities Available at field

Weather Forecasting Weather station on base

Landing Weather The airfield IFR landing weather minimum is for a 100-foot ceiling and a 1/4-mile visibility At worst, in January, this minimum occurs 4 2 percent of the time and in December, 3 8 percent of the time

Local Features Located on the flat Red River plane 3 miles west of Alexandria, Louisiana The vertical obstructions include a 235-foot high tower located 11 miles east, a 583-foot tower 7 miles east, a 260-foot tower 3 miles east, a 400-foot tower 8 miles east/northeast, a 309-foot tower 6 miles east/northeast, a 268-foot tower 17 miles west/northwest, a 209-foot tower 11 miles southwest, a 420-foot tower 13 miles southwest, and a 1,586-foot tower 17 miles south/southeast of the field

Barksdale AFB, Louisiana

Coordinates 32-30-05N, 93-39-44W

Elevation 167 ft

Runway Length x width--11,754 ft x 300 ft, extendable by 2,500 ft, surface--concrete, strength--B-52 support capability, 285 psi

Taxiways Width--150 ft, surface--concrete, strength--B-52 support capability, 285 psi

Navigational Aids ILS, GCA, DF, RBN, VORTAC, TACAN, VOR, and Approach Control

Lighting Approach, threshold, runway, taxiway, flood, obstruction, and rotating beacon

Communications Telephone, telegraph, teletype, and C/W

Controlling Agency United States Air Force

Maintenance Facilities Field maintenance, organizational maintenance, and ordinance storage facilities are available

Special Purpose Equipment Crash, fire, cargo handling, and snow removal equipment are available

Logistics Good roads, railroads, and a waterway are available

Medical Facilities Available at field

Weather Forecasting Station on base

Landing Weather The airfield IFR landing weather minimum is for a 100-foot ceiling and a 1/4-mile visibility At worst, in January, this minimum occurs 4 3 percent of the time and in December, 3 8 percent of the time

Local Features Located on the flat Red River plane on the east side of Shreveport, Louisiana The vertical obstructions include a 307-foot tower located 8 miles northeast, a 207-foot tower 7 miles northwest, a 251-foot tower 9 miles west/northwest, and a 400-foot tower located 12 miles northwest of the field

Ellington AFB, Texas

Coordinates 29-36-41N, 95-09-34W

Elevation 40 ft

Runway Length x width--9,000 ft x 150 ft, extendable by 5,000 ft, surface--concrete, strength--C-121 support capability, SWL = 40,000 lb, 650 psi

Taxiways Width--75 ft, surface--concrete, strength--C-121 support capability, SWL = 40,000 lb, 650 psi

Navigational Aids GCA, TACAN, VOR, and Approach Control

Lighting Approach, threshold, runway, taxiway, flood, obstruction, and rotating beacon

Communications Telephone, telegraph, teletype, and C/W

Controlling Agency United States Air Force

Maintenance Facilities Depot maintenance, field maintenance, organizational maintenance, and ordinance storage facilities are available

Special Purpose Equipment Crash, fire, and cargo handling equipment are available

Logistics Good roads, railroads, and a waterway are available

Medical Facilities Available at field

Weather Forecasting Station on base

Landing Weather The airfield IFR landing weather minimum is for a 200-foot ceiling and a 1/2-mile visibility At worst, this minimum occurs 7 0 percent of the time in January and 6 3 percent of the time in December

Local Features Located on the flat Gulf Coast plane within the Houston area It is surrounded on the north, east, and west by about 20 structures less than 700 feet high within about 15 miles of the field The highest structure is 1,198 feet high and located 9 miles south/southwest of the field

Laughlin AFB, Texas

Coordinates 29-22-00N, 100-47-00W

Elevation 1,081 ft

Runway Length x width--8,857 ft x 150 ft, estimated extendable, surface--asphalt, strength--C-130 support capability, 95 psi

Taxiways Width--75 ft, surface--asphalt, strength--C-135 support capability, 143 psi

Navigational Aids ILS, GCA, DF, RBN, VORTAC, TACAN, VOR, and Approach Control.

Lighting Approach, threshold, runway, taxiway, flood, obstruction, and rotating beacon.

Communications Telephone, telegraph, teletype, and C/W.

Controlling Agency United States Air Force

Maintenance Facilities Field maintenance, organizational maintenance, and ordinance storage facilities are available

Special Purpose Equipment Crash, fire, and cargo handling equipment are available

Logistics Good roads and railroads are available

Medical Facilities Available at field

Weather Forecasting Station on base.

Landing Weather The airfield IFR landing minimum is for a 200-foot ceiling and a 1/2-mile visibility At worst, in January, this minimum occurs 6 6 percent of the time and in February, 4.4 percent of the time

Local Features Located in the relatively flat Rio Grande River plane about 5 n mi east of the city limits of Del Rio The vertical

obstructions include a 300-foot tower located 5 miles west, a 460-foot tower located 5 miles west/southwest, a 316-foot tower 8 miles northwest, and a mountain range rising up to 7,000 feet in elevation about 60 miles southwest of the airfield

Honolulu International/Hickam AFB, Hawaii

Coordinates 21-19-33N, 157-55-18W

Elevation 13 ft.

Runway Length x width--12,371 ft x 200 ft, not extendable, surface--asphalt, strength--SWL = 110,000 lb, 285 psi

Taxiways Widths--100 ft and 150 ft, surface--asphalt, strength--SWL = 110,000 lb, 285 psi

Navigational Aids ILS, VORTAC, RBN, ASR, UHF/VHF/DF, and Approach Control

Lighting Rotating beacon, obstruction, threshold, taxiway, high-intensity on runway 08/26, medium-intensity on runways 04L/22R and 04R/22L, flush-type on runway 04R/22L, and VASI (visual approach slope indicator system) on runway 04L

Communications Hawaiian telephone and telegraph, teletype, and radio available

Controlling Agency Federal Aviation Administration and United States Air Force

Maintenance Facilities All types of maintenance and repair services available

Special Purpose Equipment Two FFN crash trucks, fifteen 5,000-foam fire trucks, wreckage removal equipment, and cargo handling equipment available

Search and Rescue Honolulu Rescue Coordination Center has extra-long-range aircraft, medium-range rotary wing aircraft, and rescue vessels.

Medical Facilities A 6,486-bed USAF dispensary, 1,500-bed Tripler Army Hospital at Moanalua, 42-bed Naval Medical Facilities at Pearl Harbor, and 14 civilian hospitals on island

Logistics Excellent roads, standard gauge railroads, Honolulu Harbor and Pearl Harbor available

Weather Forecasting U S Weather Bureau station at airfield provides 24-hour forecasting

Landing Weather The airfield IFR landing weather minimum is for a 200-foot ceiling and a 1/2-mile visibility This minimum occurs near zero percent of the time for all months

Climate Subtropically maritime

Local Features Located on the west side of Honolulu on relatively flat terrain The area is rectangular in shape Most of the area is coral filled Area has good drainage both naturally and artificially Vertical obstructions include a mountain range with altitudes up to 3,000 ft, located 8 n mi northeast, a mountain range with altitudes up to 4,000 ft, located 9 n mi northwest, and a 260-foot high structure 6 n mi east/southeast

<u>San Nicolas Island OLF, California</u>

Coordinates 33-14-23N, 119-27-37W

Elevation 504 ft

Runway Length x width--10,000 ft x 200 ft, extendable, surface--asphalt, strength--C-118 support capability, SWL = 36,000 lb

Taxiways Width--75 ft, surface--asphalt, strength--C-118 support capability

Navigational Aids GCA, TACAN, and RBN

Lighting Threshold, runway, obstruction, and rotating beacon

Communications Telephone and teletype

Controlling Agency United States Navy Drone and Missile Operations

Maintenance Facilities Limited facilities available

Special Purpose Equipment Crash, fire, and cargo handling equipment available

Medical Facilities Available

Logistics No roads or railroads, but a navigable waterway is available

Weather Forecasting Station on base

Landing Weather The airfield IFR landing weather minimum is for a 300-foot ceiling and a 1 0 n mi visibility At worst, during each of the months of July and August, the minimum occurs at most 13 percent of the time

Local Features Located about 6 n mi west of Los Angeles on San Nicolas Island, where the highest point is 907 feet, located 2 n mi west/northwest of the field

Darwin, Australia

Coordinates 12-25-00S, 130-52-20E

Elevation 104 ft

Runway Length--11,000 ft, surface--asphalt, strength--B-52 and B-707 support capability

Taxiways Capacity restricted

Navigational Aids ILS, RBN, VAR, DME, VDF, VOR, and Approach Control

Lighting Rotating beacon, high-intensity approach lighting, variable electric flare path, toledo flares available, sideline blue taxiway lighting, obstruction lights on towers, and VASI available

Communications Telephone, telegraph, teletype, cable, C/W, and radiophone

Controlling Agency Royal Australian Air Force and Australian Department of Civil Aviation

Maintenance Facilities Base presently has field maintenance capability Additional facilities are under construction

Special Purpose Equipment One early rescue vehicle, one general purpose tender, one ambulance, three 6 by 6 fire trucks, two fire tenders, three water tankers, one 10-ton crane, one 50-ton crane, one 3 to 5 ton Fowler crane, one 3-ton general purpose crane, and cargo handling equipment

Search and Rescue Darwin Search and Rescue Center had medium- and long-range aircraft and ships available

Medical Facilities Twelve-bed sick quarters on base operated by the RAAF Complete hospital facilities in Darwin

Logistics Roads good, narrow-gauge railroad available, port facilities at Darwin Harbor, military vehicles available

Weather Forecasting Available on a 24-hour basis

Landing Weather The airfield IFR landing weather minimum is for a 400-foot ceiling and a 3/4-mile visibility At worst, during each of the months of January, February, and April, this minimum occurs 3 percent of the time

Climate Tropical

Local Features Located on the northeast edge of Darwin The surroundings are undulating and timbered with trees and swamp to the northeast The airfield open drains are adequate There are few vertical obstructions of importance

Perth International, Australia

Coordinates 31-55-54S, 115-58-06E

Elevation 69 ft

Runway Length x width--10,300 ft x 150 ft, surface--asphalt, strength--SWL = 56,600 lb, 155 psi

Taxiways Width--75 ft and 50 ft, surface--asphalt, strength--SWL = 56,600 lb, 155 psi

Navigation Aids ILS, VOR, DME, RBN, and a locator beacon

Lighting Runway, threshold, taxiway, field, obstruction, rotating beacon, and approach

Communications Telephone, telegraph, cable, civil radio, and teletype Duplex circuits connect Perth, Sydney, Darwin, and Cocos Island

Controlling Agency Australian Department of Civil Aviation

Maintenance Facilities Organizational-type facilities for routine maintenance

Special Purpose Equipment Five crash vehicles, fire equipment, cargo handling equipment, and wreckage removal equipment available

Search and Rescue Rescue coordination center on field with short and medium range aircraft and boats available

Medical Facilities First aid and ambulance on field, several hospitals in Perth

Logistics Roads are excellent, double-track narrow gauge railroad at Guilford 3 miles northeast, deep-water port at Fremantle

Weather Forecasting Station on base provides 24-hour forecasting

Landing Weather The airfield IFR landing weather minimum is for a 300-foot ceiling and a 3/4-mile visibility At worst, during the month of May, this minimum occurs 1 0 percent of the time

Local Features Located 2 n mi east of Perth and surrounded by a developing surburban area The airfield property comprises about 3,558 acres of land area with a very good drainage system The airfield is west of a hilly area and is on a flat swampy plane between the sea and the hills Vertical obstructions include hills with elevations up to 1,300 feet about 5 n mi east of the airfield, a 591-foot high structure located 3 n mi west, a 257-foot high structure located 8 n mi southwest, and a 475-foot high (1,585 feet in elevation) structure located 8 n mi southeast

Significance Perth International was used by heavy bombers of the RAAF in World War II. Improved and expanded in recent years, it is now utilized by heavy jet transport aircraft and is one of the two major air facilities in western Australia Excellent surface transportation facilities exist in the area

Nandi International, Fiji Islands

Coordinates 17-46-00S, 177-27-00E

Elevation 63 ft

Runway Length x width--10,500 ft x 150 ft, not extendable, surface--concrete, strength--SWL = 65,100 lb, 190 psi

Taxiways Width--75 ft, surface--concrete and asphalt, strength--SWL = 65,100 lb, 190 psi

Navigational Aids ILS, RBN, VOR, VHF/DF, Approach Control

Lighting Beacon, approach, runway, taxiway, threshold, obstruction, flood, and tetrahedron

Communications Fiji commercial telephone, duplex RATT to Honolulu, cable, and telegraph

Controlling Agency New Zealand Civil Aviation Administration

Maintenance Facilities Accommodations for full base maintenance and repair services

Special Purpose Equipment One rescue unit, two ambulances, four general purpose vehicles, four 500-gallon fire trucks, four 1,400-gallon fire trucks, two CO_2 units, 16 baggage trolleys and towing units, one 1 5-ton A-crane, and one 3-ton crane

Search and Rescue Long-range aircraft, a rescue vessel, and a rescue boat

Medical Facilities 100-bed hospital on base

Airfield Security Fiji police have a small unit at the airfield

Logistics Roads fair, private sugar cane trains, full port facilities at Lautoka and Suva

Weather Forecasting 24-hour forecasting from the New Zealand Meteorological Service

Landing Weather The airfield IFR landing weather minimum is for a 400-foot ceiling and a 3/4-mile visibility At worst, during each of the months of January, February, and March, the minimum occurs 2 percent of the time

Climate Maritime tropical

Local Features Located 6 n mi south/southwest of Nandi on a small area of fairly flat country located on the west by Nandi Bay and on the north, east, and south by mountains and hills The closest is the Sambeto Mountain Range lying 3 miles to the north and rising to a height of 2,030 ft Other vertical obstructions include a 3,921-foot

altitude peak located 9 n mi northeast and a 3,528-foot altitude peak located 10 n mi southeast Drainage is artificial and good

Significance The leading and best-equipped airfield in the south central Pacific Excellent for recovery and turnaround of most types of aircraft

La Tontouta, New Caledonia

Coordinates 22-01-01S, 166-12-39E

Elevation 52 ft

Runway Length x width--10,663 ft x 148 ft, not extendable, surface--asphalt, strength--SWL = 46,000 lb, 155 psi

Navigational Aids ILS, RBN, and VOR

Lighting Approach, threshold, runway, taxiway, obstruction, visual, VASI, and temporary

Communications Local telephone, telegraph to Noumea, point-to-point radio to Noumea, and international radio circuits to Noumea

Controlling Agency Civil Aviation Administration, Directorate of Civil Aviation (AVA/DAC)

Special Purpose Equipment Three ambulances, one 792-gallon Berliet fire truck, one 132-gallon Simca fire truck, one 1,453-gallon Berliet fire truck with 370 gallons of foam, one 926-lb bromofluoride and carbon dioxide Hotchkiss truck, one 926-lb bromofluoride Latil truck, one 661-lb bromofluoride jeep trailer, wreckage removal equipment, and airline-type cargo handling equipment

Search and Rescue Limited SAR facilities at Noumea, a small military unit with two helicopters on call New Caledonia is within the responsibility of SAR facilities at Lauthala Bay, Fiji Islands

Medical Facilities An infirmary on the base and a hospital and clinics in Noumea

Logistics Roads are winding and mountainous, with an all-weather road in fair condition to Noumea 35 miles away A short line narrow gauge railroad runs from Paita to Noumea

Weather Forecasting Forecasts by the French Weather Service located at the airfield and Noumea

Landing Weather The airfield IFR landing weather minimum is for a 300-foot ceiling and a 1 0-mile visibility At worst, during each of the months of February and April, the minimum occurs 2 percent of the time

Climate Tropical

Local Features Located near the western slope of New Caledonia about 21 n mi northwest of Noumea on a relatively flat area between a mountain range and the ocean The drainage is adequate. Vertical obstructions include a mountain range running northwest to southeast with many peaks above 4,500 ft The range is 10 n mi northeast of La Tontouta

Lusaka International, Zambia

Coordinates 15-19-45S, 28-27-10E

Elevation 3,779 ft

Runway Length--13,000 ft, extendable, surface--asphalt, strength--SWL = 106,000 lb, 270 psi

Taxiways Width--75 ft, surface--asphalt, strength--SWL = 65,000 lb, 190 psi

Navigational Aids ILS, ASR, DF, VHF, four non-directional beacons, VOR/DME, and Approach Control

Lighting Approach, slope indicators, threshold, touchdown baretts, runway centerline and edge, red stop bar, green taxiway centerline and blue edge, flood, obstruction, rotating beacon, and emergency flares

Communications Telephone, telegraph, teletype, and cable service at airfield

Controlling Agency Government Civil Aviation Authority

Special Purpose Equipment Wreckage removal equipment available and cargo handling equipment available at the Zambia Airways

Search and Rescue Short and medium-range aircraft Related ATS units at Livinstone and Ndola

Logistics Roads good, railroads good, major port available

Weather Forecasting Station on base meets ICAO standards

Landing Weather The airfield IFR landing weather minimum is for a 300-foot ceiling and a 1 0-mile visibility At worst, the minimum occurs 1 0 percent of the time for any month

Climate Tropical savanna, coller uplands climate

Local Features Located 7 n mi northeast of Lusaka on a high (4,000-foot elevation), undulating plateau with sandy loam soil and scattered scrub Approaches are over flat terrain, except for a 200-foot hill 4 miles west Vertical obstructions include a 4,867-foot elevation peak located 10 n mi southeast and a 4,593-foot elevation peak 15 n mi northeast

Significance This is a new airfield and is the best in this part of Africa and will increase in importance

<u>Kadena AB, Ryukyu Islands</u>

Coordinates 26-21-08N, 127-46-15E

Elevation 142 ft

Runway Length x width--12,100 ft x 300 ft, extendable by 2,400 ft, surface--concrete, strength--SWL = 155,000 lb, 285 psi

Taxiways Widths--300 ft by 100 ft, and 75 ft, surface--concrete, strength--SWL = 105,590 lb, 285 psi

Navigational Aids ILS, ASR, PAR, VOR, RBN, TACAN, and Approach Control

Lighting Runway, approach, taxiway, obstructions, security, threshold, and rotating beacon

Communications Worldwide telephone, duplex teletype, major stratcom relay, telegraph, cable, C/W, and radiophone, U S communication facilities

Maintenance Facilities All maintenance and repair services are available

Special Purpose Equipment Three 0-11, two R-2, and two P-2 crash and rescue units, six field and four civil ambulances, two 750-gallon pumpers, four 530-gallon pumpers, four pumper units, four 1,000-gallon tankers, one 1,500-gallon tanker, one 1-1/2 stake unit,

two P-6 ramp control units, one 50-ton crane, two 20-ton cranes, seven truck wreckers, 13 MB-2 aircraft towing tractors, 22 MB-4 aircraft towing tractors, 12 25-foot and 25 40-foot trailers are all available

Search and Rescue Helicopters are available

Medical Facilities One hospital is available

Airfield Security The 824th Support Squadron provides 24-hour security and has 84 dog handlers

Logistics Excellent roads, no railroads, several ports on Okinawa

Weather Forecasting 24-hour forecasting by Det 8, 20th Squadron

Landing Weather The airfield IFR landing weather minimum is for a 200-foot ceiling and a 1/2-mile visibility At worst, during each of the months of May, June, August, and September, the minimum occurs 1 0 percent of the time

Climate Warm temperature climate

Local Features Located on the western shore of Okinawa-Jima on a mostly level clay and coral terrain A 360-foot high structure is located 1 0 n mi south The drainage is good, and the airfield is not subject to flooding

N Djili, Congo

Coordinates 4-23-05S, 15-26-42E

Elevation 1,014 ft

Runway Length x width--15,420 ft x 197 ft, extendable by 1,400 ft, surface--concrete, strength--SWL = 99,200 lb, 140 psi

Taxiways Width--100 ft, surface--concrete, strength--SWL = 99,200 lb, 140 psi

Navigational Aids ILS, VOR, RBN, D/F, and locator

Lighting Rotating light, approach, threshold, runway, taxiway, apron floods, wind indicator, obstruction, and flares

Communications U S communications facilities

Controlling Agency Congolese Directorate of Civil Aeronautics

Maintenance Facilities All types of aircraft maintenance shops and personnel are available, capabilities limited by limited personnel

Special Purpose Equipment Two ambulances, five fire trucks containing water, CO_2 foam, and powder

Medical Facilities 10-bed dispensary on base with doctors and nurses on call from hospitals in Kinshasa

Airfield Security Responsibility of city police

Logistics Four-lane asphalt road to Kinshasa, a single-track railroad spur to airfield from Kinshasa

Landing Weather The airfield IFR landing weather minimum is for a 300-foot ceiling and a 1 0-mile visibility At worst, during each of the months of February, May, June, and November, the minimum occurs 1 0 percent of the time

Climate Tropical savanna

Local Features Located 8 n mi east/southeast of Leopoldville in the flat, swampy terrain surrounding the Congo River The approach terrain is flat, with trees and bushes on all sides of the field Vertical obstructions include a 2,379-foot elevation hill at 14 n mi southeast, a 2,700-foot elevation hill at 35 n mi northwest, and a 236-foot high structure at 8 n mi northwest

Andersen AFB, Guam

Coordinates 13-34-52N, 144-55-28E

Elevation 624 ft

Runway Length x width--11,200 ft x 200 ft, extendable by 3,000 ft, surface--concrete, strength--SWL = 110,000 lb, 285 psi

Taxiways Width--200 ft, surface--concrete, strength--110,000 lb, 285 psi

Navigational Aids GCA, VOR, TACAN, RBN, omni, UHF-VHF/DF, and Approach Control

Lighting Runway, threshold, taxiway, obstruction, approach, rotating beacon, and boundary

Communications Island telephone integrated with three automatic USN exchanges, teletype, radio teletype, radio telephone, radio telegraph, and cable facilities

Controlling Agency United States Air Force

Maintenance Facilities Full maintenance capability available on assigned aircraft

Special Purpose Equipment Seven crash trucks, six ambulances, 10 fire trucks, two 15,000-lb fork lifts, and 31 4,000 to 6,000 lb fork lifts

Search and Rescue SAR Guam Rescue Coordination Center with aircraft, helicopters, and one sea-going rescue vessel

Medical Facilities 25-bed dispensary on base and a 350-bed U S Naval Hospital 11 miles southeast of the base

Logistics Good roads, no railroads, and a good harbor nearby

Weather Forecasting USAF Weather Station on the base

Landing Weather The airfield IFR landing weather minimum is for a 300-foot ceiling and a 3/4-mile visibility At worst, during each of the months of January, February, August, September, and October, the minimum occurs 1 0 percent of the time

Climate Maritime tropical modified by dry northeast trade winds

Local Features Located on the northeast shore of Guam, with no major vertical obstructions

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Ramey AFB, Puerto Rico

Coordinates 18-29-39N, 67-07-47W

Elevation 237 ft

Runway Length x width--11,700 ft x 300 ft, surface--concrete, strength--SWL = 105,590 lb, 285 psi

Taxiways Widths--75 ft, 100 ft, and 150 ft, surfaces--concrete and asphalt, strength--105,590 lb, 285 psi

Navigational Aids ILS, TACAN, VOR, RBN, UHF/DF, GCA, and Approach Control

Search and Rescue San Juan Island Rescue Control Center with extra long range, very long range, and long range aircraft available

Logistics Military highway from San Juan to Ramey AFB, no railroad

Weather Forecasting Air Weather Service (USAF) at Ramey and U S Weather Bureau Forecast Office at San Juan

Landing Weather The airfield IFR landing weather minimum is for a 300-foot ceiling and a 1/2-mile visibility The minimum occurs zero percent of the time for all months

Climate Tropical rain forest

Local Features Located on the northwest shore of Puerto Rico on a relatively flat plain between mountains and the sea Vertical obstuctions include a 400-foot high structure located 4 n mi southeast, a 1,207-foot high peak located 9 n mi southeast, a 3,953-foot high peak located 29 n mi southeast, and a 4,390-foot high peak located 39 n mi southeast

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